

Accelerometer
M-A351AS
M-A351AU
Data Sheet

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1. GENERAL DESCRIPTION

Accelerometer M-A351 (vibration and inclination) series is a wideband model with wider measurement bandwidth capability compared to the M-A350 series. The M-A351 series enables measurement bandwidths of up to 100Hz, and an increased data output rate of up to 1000Sps. Moreover, the measurement resolution is improved to 0.06uG/LSB, and the output mode of each acceleration axis can be selected from acceleration/tilt angle/tilt angle speed. All other features and performance are the same as found in the M-A350 series - a highly accurate and stable three axis accelerometer equipped with detection elements made from quartz crystal micro-fabrication technology and wide temperature range by incorporating built-in temperature compensation technology.

Using the M-A351 series with the latest generation technology eliminates the need for costly components such as high fidelity AD converters, analog accelerometers, and noise/wiring challenges associated with legacy analog systems. The highly integrated M-A351 series with serial digital output (SPI or UART) simplifies the design of high performance measurement systems by reducing the overall system cost, weight, and power consumption.

The M-A351 series accelerometer facilitates the differentiation and development of new applications in the various fields of industrial systems.

FEATURES

- | | |
|-------------------------------------|---|
| • Small Size and Lightweight | : 24x24x19mm, 12grams |
| • Low Noise | : 0.5uG/ $\sqrt{\text{Hz}}$ (Average) |
| • High Resolution | : 0.06uG/LSB |
| • Wide Bandwidth | : 100Hz (selectable) |
| • Output Rate | : 1000Sps (selectable) * SPI Max.500Sps |
| • Three Axis Accelerometer | : $\pm 5\text{G}$ |
| • Digital Serial Interface | : SPI (M-A351AS) / UART (M-A351AU) |
| • Wide Operating Temperature Range | : -20°C to +85°C |
| • Low Voltage Supply | : 3.3 V |
| • Low Power Consumption | : 66mW |
| • Output Mode Selection (each axis) | : Acceleration, Tilt Angle, or Tilt Angle Speed |

APPLICATIONS

- Building and Structural Health Monitor
- Seismic Observation
- Earthquake Detection

FUNCTIONAL BLOCK DIAGRAM

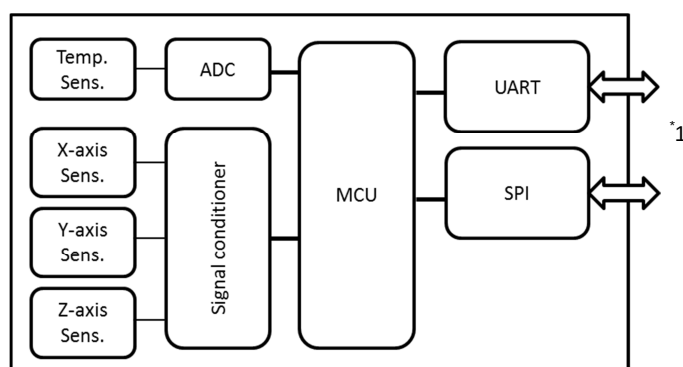


Figure 1.1 Block Diagram

* 1 The serial interface type can be UART or SPI and must be specified at the time of order. UART:M-A351AU, SPI:M-A351AS

2. PRODUCT SPECIFICATIONS

2.1 ABSOLUTE MAXIMUM RATINGS

Table 2.1 Absolute Maximum Rating

Parameter	Condition	Min	Typ	Max	Unit
Power Supply Voltage Range		-0.3		3.6	V
Input Voltage	Reference to GND	-0.3		3.6	V
Output Voltage	Reference to GND	-0.3		3.6	V
Storage Temperature Range	No condensation	-20		+85	°C
Acceleration / Shock	1 msec half-sine			300	G
ESD ^{*1}	Human Body Model (100pF, 1.5kΩ)	-1000		1000	V
	Machine Model (200pF, 0Ω)	-200		200	

^{*1} Precautions concerning ESD.

Electrostatic Discharge (ESD) may damage this product.

Please take appropriate measures against Electrostatic Discharge (ESD) when storing and handling this product.

Damage by Electrostatic Discharge (ESD) can cause very small performance deterioration, partial malfunction, or complete breakdown.

This is a high precision product and may not conform to specification even with very small performance degradation due to improper usage or handling.

2.2 RECOMMENDED OPERATING CONDITION

Table 2.2 Recommended Operating Conditions

Parameter	Condition	Min	Typ	Max	Unit
Power Supply Voltage Range	VCC to GND	3.15	3.3	3.45	V
Input Voltage		GND		VCC	V
Output Voltage		GND		VCC	V
Operational Temperature Range	No condensation	-20		+85	°C

2.3 PERFORMANCE & ELECTRICAL SPECIFICATIONS

Table 2.3 Sensor Specification

Condition: $T_A = -20^{\circ}\text{C} \sim +85^{\circ}\text{C}$, $V_{CC} = 3.15\text{V}$ to 3.45V , and $\pm 1\text{G}$, unless otherwise specified.

Parameter	Condition / Comment	Min	Typ	Max	Unit
Data Output Rate ^{*1}	UART			1000	Sps
	SPI			500	Sps
Continuous Operation Stabilization Time	Time from $T_A = 25^{\circ}\text{C}$ and power supply turn-on		15		minutes
Current Consumption	512 Tap, continuous measurement mode		20	27	mA
MTBF ^{*2}	JIS-C5003	87,600			hour
Temperature Resolution			0.001		$^{\circ}\text{C}/\text{LSB}$
Temperature Output ^{*3}		-25		+90	$^{\circ}\text{C}$
Resonant Frequency			790		Hz

NOTE: The Max/Min value is the maximum/minimum value of the design or factory shipment examination, unless otherwise specified.

^{*1} The data output rate can be changed by user command. The data output rate of 1000Sps is only supported for either external trigger measurement or timer measurement for the UART interface.

^{*2} The MTBF is an estimated value derived from the result of high temperature operation with a system requirement of $T_A = 25^{\circ}\text{C}$ and a 60% reliability level.

^{*3} The temperature output is a reference value used for the internal temperature correction, and is not guaranteed to accurately output the interior temperature.

Table 2.4 Sensor Specification (Acceleration)

Condition: $T_A = -20^{\circ}\text{C} \sim +85^{\circ}\text{C}$, $V_{CC} = 3.15\text{V}$ to 3.45V , and $\pm 1\text{G}$, unless otherwise specified.

Parameter	Condition / Comment	Min	Typ	Max	Unit
Input Range ^{*1}	Reduced accuracy operating range	-5		+5	G
Input Range ^{*2}	Accuracy guaranteed by specification	-1		+1	G
Null Offset	$T_A = 25^{\circ}\text{C}$	-4		+4	mG
Null Offset Repeatability	$T_A = 25^{\circ}\text{C}$ and $V_{CC} = 3.3\text{V}$ for one year after shipment		3		mG
Null Offset Temperature Variation	-20°C to $+85^{\circ}\text{C}$	-4		+4	mG
Axis Alignment Error	$T_A = 25^{\circ}\text{C}$	-0.1		+0.1	deg
Non-Linearity	$T_A = 25^{\circ}\text{C}$, $\pm 1\text{G}$	-0.03		+0.03	%
Noise Density	$T_A = 25^{\circ}\text{C}$, average 0.5Hz to 6Hz, horizontal (± 5 deg)		0.5	2	$\mu\text{Grms}/\sqrt{\text{Hz}}$
	$T_A = 25^{\circ}\text{C}$, peak 0.5Hz to 100Hz, horizontal (± 5 deg)			60	$\mu\text{Grms}/\sqrt{\text{Hz}}$
Resolution	UART / SPI (Binary)		0.06		$\mu\text{G}/\text{LSB}$

NOTE: The Max/Min value is the maximum/minimum value of the design or factory shipment examination, unless otherwise specified.

^{*1} The range from above $\pm 1\text{G}$ to $\pm 5\text{G}$ is outside the guaranteed accuracy specifications.

^{*2} The calibrated standard 1G gravitational acceleration value is 9.80665 m/s^2 .

Table 2.5 Sensor Specification (Tilt Angle)

Condition: $T_A = -20^{\circ}\text{C} \sim +85^{\circ}\text{C}$, $V_{CC} = 3.15\text{V}$ to 3.45V , and $\pm 45\text{deg}$, unless otherwise specified.

Parameter	Condition / Comment	Min	Typ	Max	Unit
Input Range ^{*1}	Reduced accuracy operating range	-1.047		+1.047	rad
Input Range ^{*2}	Accuracy guaranteed by specification	-0.785		+0.785	rad
Null Offset Repeatability	$T_A = 25^{\circ}\text{C}$ and $V_{CC} = 3.3\text{V}$ for one year after shipment		± 3.491		mrad
Null Offset Temperature Variation	-20°C to $+85^{\circ}\text{C}$	-4.014		+4.014	mrad
Axis Alignment Error	$T_A = 25^{\circ}\text{C}$	-1.745		+1.745	mrad
Non-Linearity	$T_A = 25^{\circ}\text{C}$, $\pm 45\text{deg}$.	-0.03		+0.03	%
Noise Density	$T_A = 25^{\circ}\text{C}$, average 0.5Hz to 6Hz, horizontal ($\pm 5\text{ deg}$)		0.5	2	$\mu\text{rad}/\sqrt{\text{Hz}}$
Resolution	UART / SPI (Binary)		0.002		$\mu\text{rad}/\text{LSB}$

NOTE: The Max/Min value is the maximum/minimum value of the design or factory shipment examination, unless otherwise specified.

^{*1} The range between $\pm 45\text{deg}$ to $\pm 60\text{deg}$ is outside the guaranteed accuracy specifications.

^{*2} The calibrated standard 1G gravitational acceleration value is 9.80665 m/s^2 .

The tilt angle is internally calculated from gravitational acceleration by the following expression.

Tilt Angle Calculation Formula

$$\theta = \text{asin}(G) [\text{rad}]$$

Table 2.6 Sensor Specification (Tilt Angle Speed)

Condition: $T_A = -20^{\circ}\text{C} \sim +85^{\circ}\text{C}$, $V_{CC} = 3.15\text{V}$ to 3.45V , and $\pm 45\text{deg}$, unless otherwise specified.

Parameter	Condition / Comment	Min	Typ	Max	Unit
Calculation Range	Unit per millisecond of measurement trigger	-2.094		± 2.094	rad/ms
	Unit per second of measurement trigger	-2.094		± 2.094	rad/s
Resolution	UART/ SPI (Binary), unit per milli-second of measurement trigger		2		($\mu\text{rad}/\text{s}$)/LSB
	UART/ SPI (Binary), unit per second of measurement trigger		0.002		($\mu\text{rad}/\text{s}$)/LSB

NOTE: The Max/Min value is the maximum/minimum value of the design or factory shipment examination, unless otherwise specified.

The tilt angle speed is a change of the tilt angle per unit time between the measurement intervals.

The tilt angle is internally calculated by the following expression.

Tilt Angle Speed Formula

$$\omega = (\theta_1 - \theta_0) \times \frac{1}{\text{OutputRate_ms}} [\text{rad} / \text{ms}]$$

$$\omega = (\theta_1 - \theta_0) \times \frac{1}{\text{OutputRate_s}} [\text{rad} / \text{s}]$$

θ_1 : Present tilt angle

θ_0 : Tilt angle measured in previous sample

OutputRate_ms: Value of measurement interval when command was set. Unit [ms] of measurement trigger.

OutputRate_s: Value of measurement interval when command was set. Unit [s] of measurement trigger.

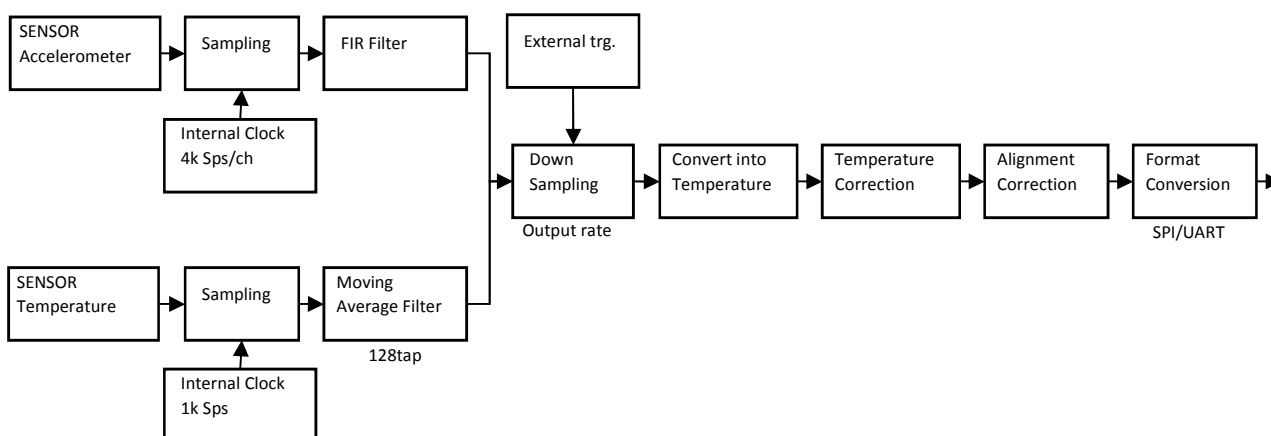


Figure 2.1 Function Block Diagram

Table 2.7 Interface Specification

$T_A=25^{\circ}\text{C}$, $V_{CC}=3.3\text{V}$, unless otherwise noted

Parameter	Test Conditions	Min	Typ	Max	Unit
LOGIC INPUTS					
Positive Trigger Voltage		1.2		2.52	V
Negative Trigger Voltage		0.75		1.98	V
DIGITAL OUTPUTS					
Output High Voltage, V_{OH}	$I_{SOURCE}=1.4\text{mA}$	2.9			V
Output Low Voltage, V_{OL}	$I_{SINK}=1.4\text{mA}$			0.4	V
FUNCTIONAL TIMES (Time until data is available)					
Power-On Start-Up Time	Include Initialization ^{*1}		2.0		s
Re-initialization Time	Reboot by the command ^{*1}		0.7		s
Measurement Wait Time	External Trig, Request command ^{*2}	220			ms

^{*1} : The device must not be accessed during initializing.

^{*2} : The device should not be triggered to measure until the elapsed time immediately after the start of measurement.

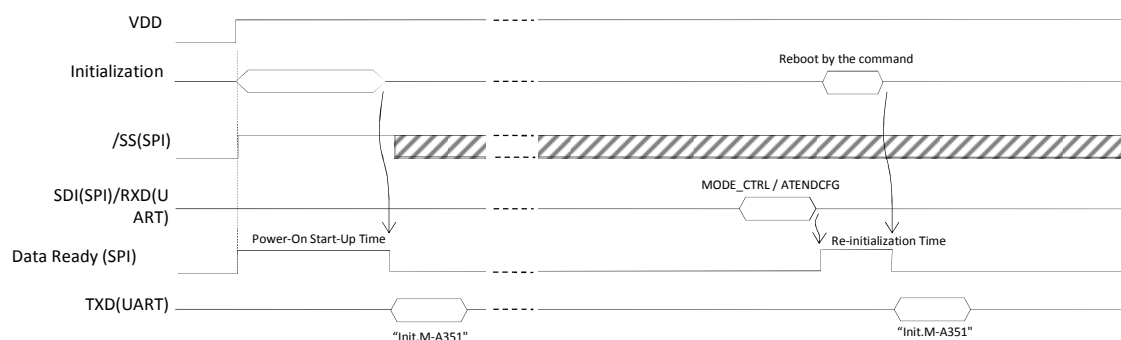


Figure 2.2 Power-on and Initialization Timing

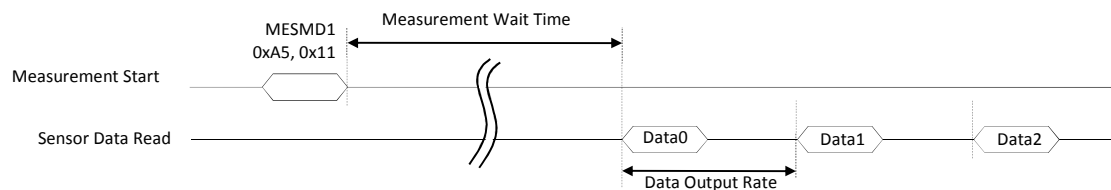


Figure 2.3 Measurement Start Timing

2.4 UART TIMING SPECIFICATIONS

Table 2.8 UART Timing Specification

$T_A=25^{\circ}\text{C}$, $V_{CC}=3.3\text{V}$, unless otherwise noted

Parameter	Description	Min	Typ	Max	Unit
Response Times	All Responses except for below 1),2),3)			4	ms
	1) REQDAT Command Response ^{*1}			1.3	ms
	2) TSTSLF Command Response			600	ms
	3) Command Reception Timeout ^{*2}			520	ms

^{*1}: The measurement interval by the request command must be 500Sps or less.

^{*2}: The timeout period from the last character reception to the "LF" reception. Following a timeout condition, the device issues an error code response of "#".

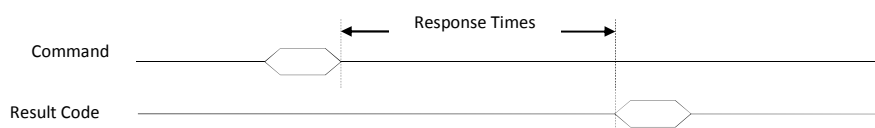


Figure 2.4 UART Response Timing

2.5 SPI TIMING SPECIFICATIONS

Table 2.9 SPI Timing Specification

$T_A=25^{\circ}\text{C}$, $V_{CC}=3.3\text{V}$, unless otherwise noted

Parameter	Description	Min	Typ	Max	Unit
fSCLK				2	MHz
tSTALL	Stall period between data	35			us
tWEXE	Write command processing times (Self-test processing times)			1 (600)	ms
tSS	Slave select to clock edge	10			ns
tDAV	SDO valid after SCLK edge			80	ns
tDSU	SDI setup time before SCLK rising edge	10			ns
tDHD	SDI hold time after SCLK rising edge	10			ns
tSCLKR, tSCLKF	SCLK rise / fall times			20	ns
tDF, tDR	SDO rise / fall times			20	ns
tSFS	/SS hold time after SCLK edge	80			ns

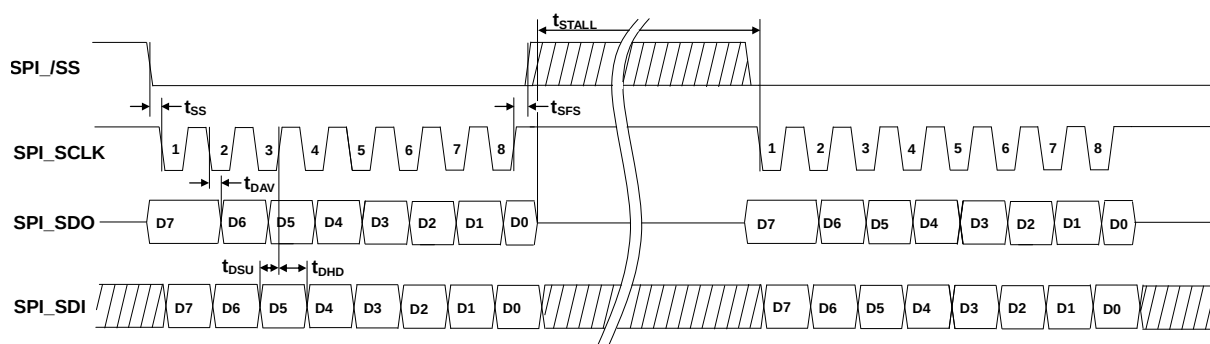


Figure 2.5 SPI Timing and Sequence 1/2

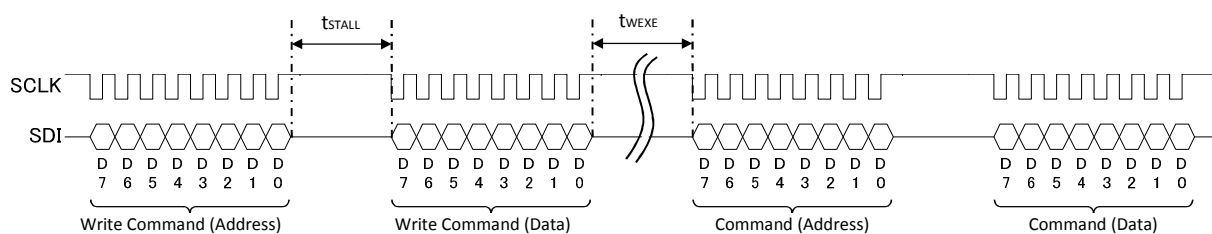


Figure 2.6 SPI Timing and Sequence 2/2

2.6 EXTERNAL TRIGGER TIMING SPECIFICATIONS

Table 2.10 External Trigger Input Timing

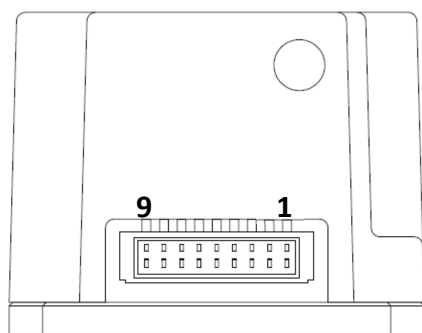
Parameter	Description	Min	Typ	Max	Unit
tETW	External Trigger Input Width	1			us
tETC ^{*1}	External Trigger Input Cycle (UART)	1			ms
	External Trigger Input Cycle (SPI)	2			ms

^{*1}: The user must set the external trigger input cycle timing interval in conjunction with the internal filter to avoid aliasing.



Figure 2.7 External Trigger Input Timing

2.7 SOCKET PIN LAYOUT AND FUNCTIONS



Connector socket in the device

Manufacturer: JST Company
Part Number: BM09B-SRSS-TB

Recommended header on the host side

Manufacturer: JST Company
Parts Number: SHR-09V-S-B (housing and knob)
SSH-003T-P0.2-H (contact)

Note:

During header insertion, ensure an axial clearance on the mating connector of less than $\pm 15^\circ$ for all side - top, bottom, left, or right.
Please refer to JST Company for more details.

Figure 2.8 Socket Pin Layout

Table 2.11 Socket Pin Function

UART (M-A351AU)

Pin No.	Mnemonic	Type	Description
9	NC	N/A	Do Not Connect
8	NC	N/A	Do Not Connect
7	EXT_TRG	I	External Trigger
6	VCC_3.3V	S	Power Supply 3.3V
5	GND	S	Ground
4	UART_TXD	O	UART Data Output
3	UART_RXD	I	UART Data Input
2	NC	N/A	Do Not Connect
1	NC	N/A	Do Not Connect

SPI (M-A351AS)

Pin No.	Mnemonic	Type	Description
9	SPI_SDI	I	SPI Data Input
8	SPI_SDO	O	SPI Data Output
7	EXT_TRG	I	External Trigger
6	VCC_3.3V	S	Power Supply 3.3V
5	GND	S	Ground
4	READY	O	SPI Data Ready
3	NC	N/A	Do Not Connect
2	SPI_SCLK	I	SPI Serial Clock
1	SPI_SS	I	SPI Slave Select

3. MECHANICAL DIMENSIONS

3.1 OUTLINE DIMENSIONS

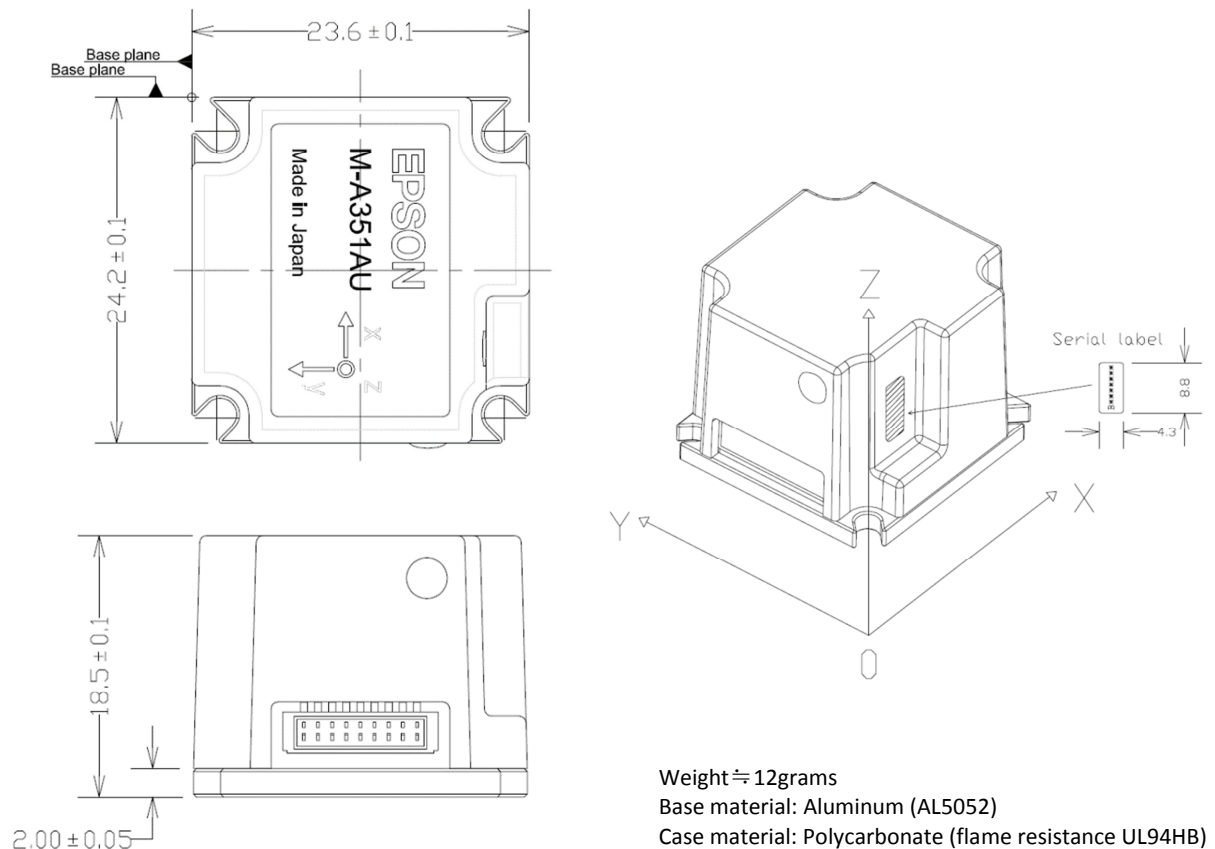


Figure 3.1 Outline Dimensions (millimeters)

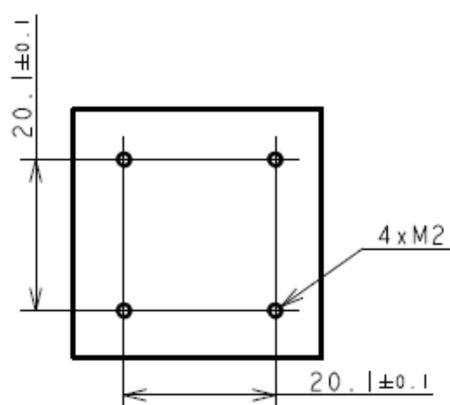


Figure 3.2 Suggested Guide Pin & Mounting Screw Hole Location (millimeters)

Please install the sensor on to a flat surface using small M2 Pan Head Screw carefully without excessive torque to cause damage or warp to the bottom flange surface. Refer to Figure 3.2 for the position of the mounting screw holes.

4. TYPICAL PERFORMANCE CHARACTERISTICS

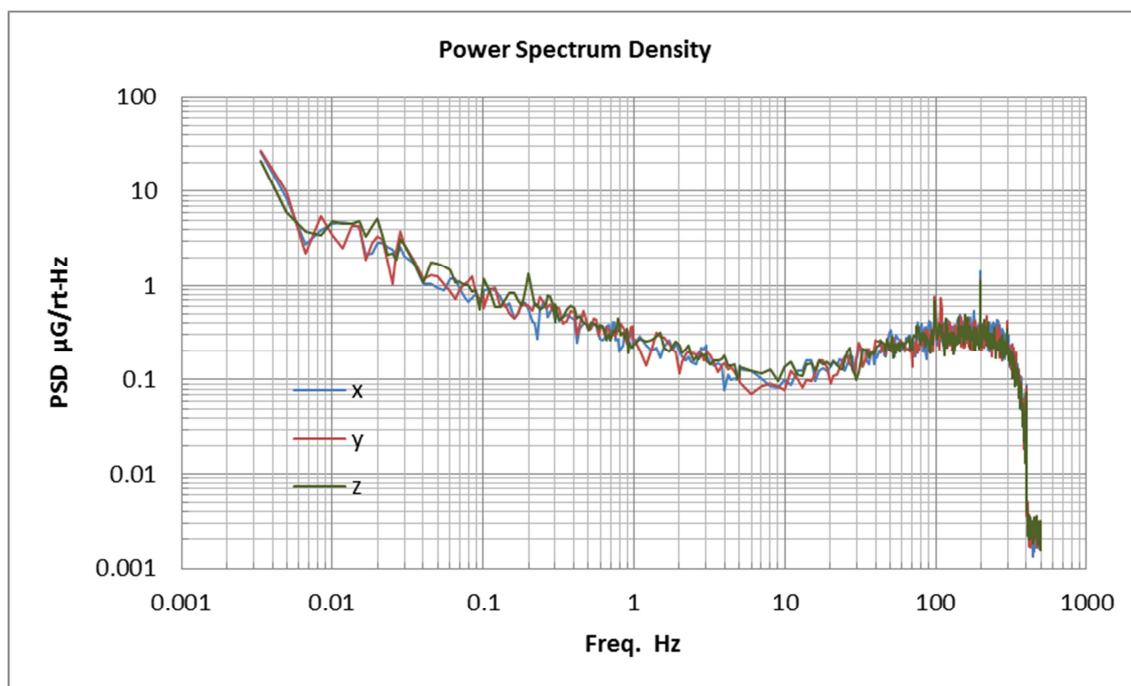


Figure 4.1 Noise Density Characteristic

The above graph is a typical example of the product characteristics, and is not guaranteed by the specification.

5. BASIC OPERATION

5.1 CONNECTION TO HOST

There are two versions of this device (UART and SPI). The interface type must be specified at the time of order. The example wiring connection is provided below as a reference.

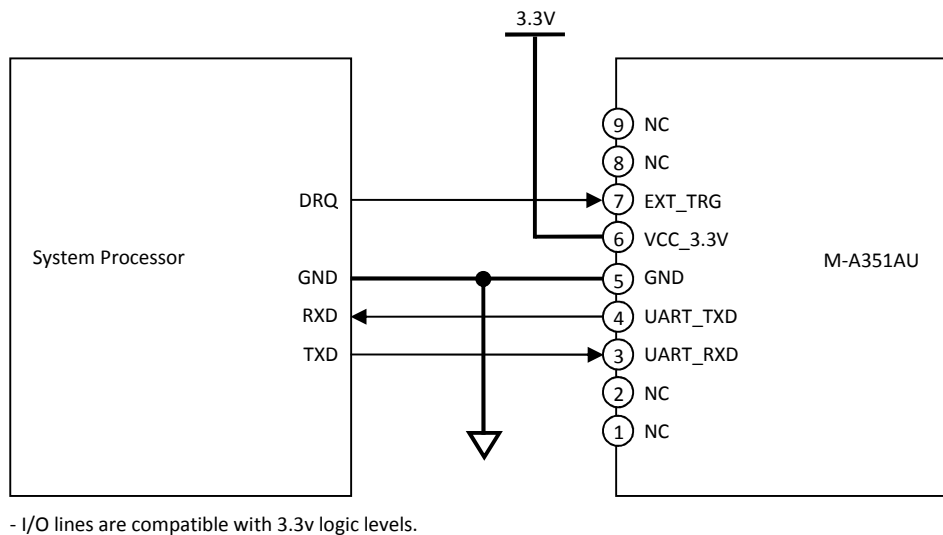


Figure 5.1 UART Connection (M-A351AU)

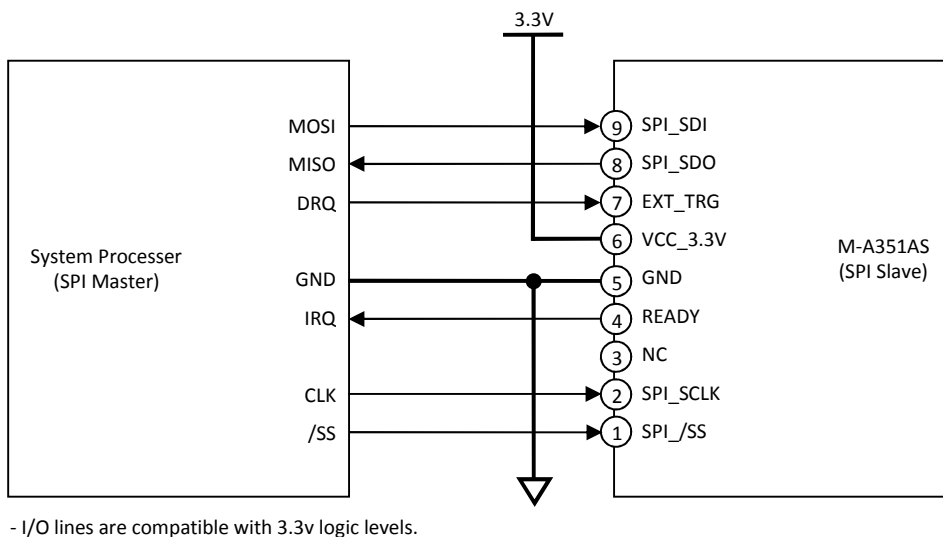


Figure 5.2 SPI Connection (M-A351AS)

The device performance may be affected by signal overshoot or undershoot of the host interface. Care must be taken to minimize signal integrity issues when designing the electrical interface so that the noise level is reduced as much as possible to within the tolerance of the communication timing specification.

5.2 OPERATION MODE

The following operational modes are available in the device.

- IDLE mode
- CONFIG mode
- MEASUREMENT mode

The transitioning between these modes are controlled by AT commands in the UART interface or control registers in the SPI interface. Please refer to Chapter 6 for details of each interface.

5.2.1 STATE TRANSITION

The device begins Internal Initialization immediately after power is supplied. After initialization completes, the device enters IDLE Mode. The device transitions to various operational modes by executing commands sent by the host. The state transition chart is described as below.

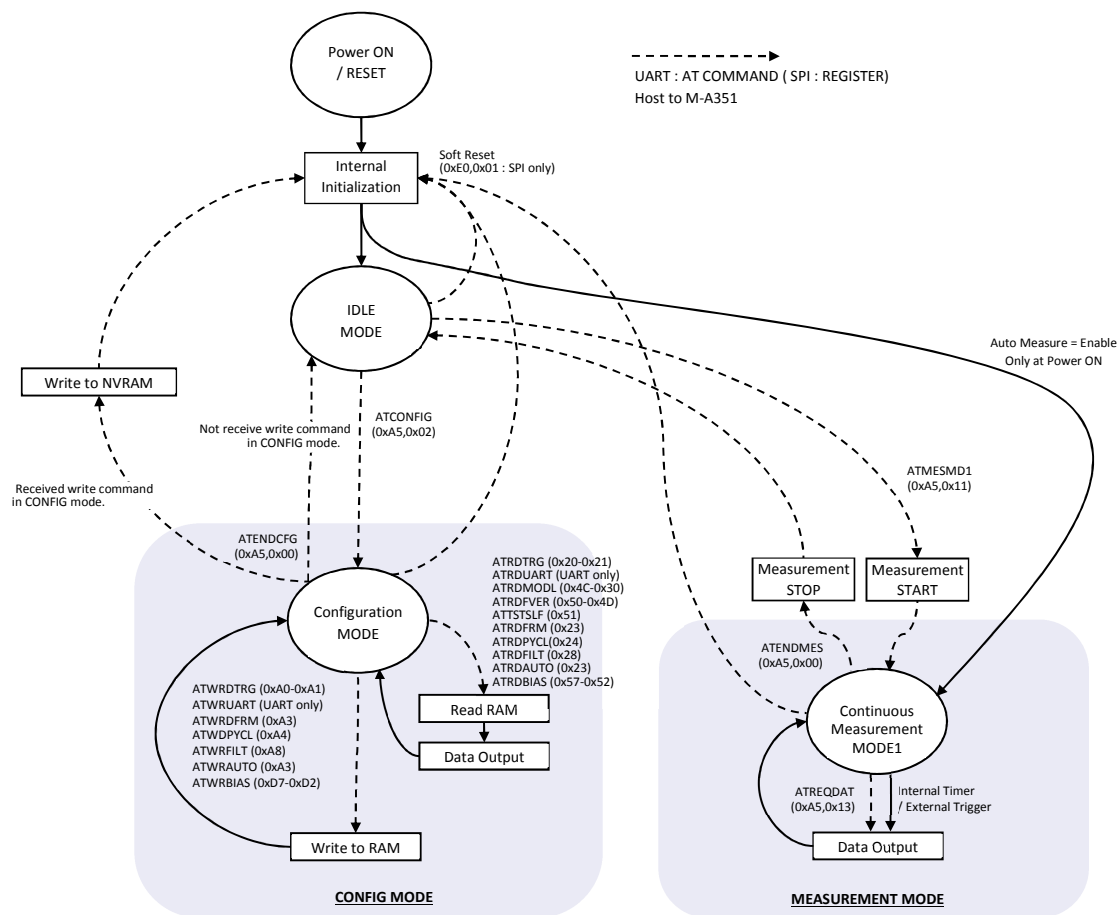


Figure 5.3 State Transition Diagram

5.2.2 LED DISPLAY FUNCTION

This device displays the operational mode status by an LED blinking pattern. The display pattern is described as follows.

Table 5.1 Display Pattern and Operational Mode

Pattern	Mode (state)	Description
0	Set factory default state	Indicates the device has completed the factory default state sequence
1	IDLE mode	Indicates the device is in IDLE mode
2-1	MEASUREMENT mode (normal)	Indicates the device is in MEASUREMENT mode (normal)
2-2	MEASUREMENT mode (automatic)	Indicates the device is in MEASUREMENT mode (automatic)
3	Power-supply voltage error	Indicates the power-supply voltage exceeds the supply range of 3.0 ~ 3.6 volts
4	Self-diagnosis test error	Indicates an error condition detected after completion of a self-diagnosis test
Steady ON	CONFIG mode	Indicates the device is in CONFIG mode
	Device Startup/Initialization	Indicates the device has experienced a startup failure if the LED stays ON continuously after power on

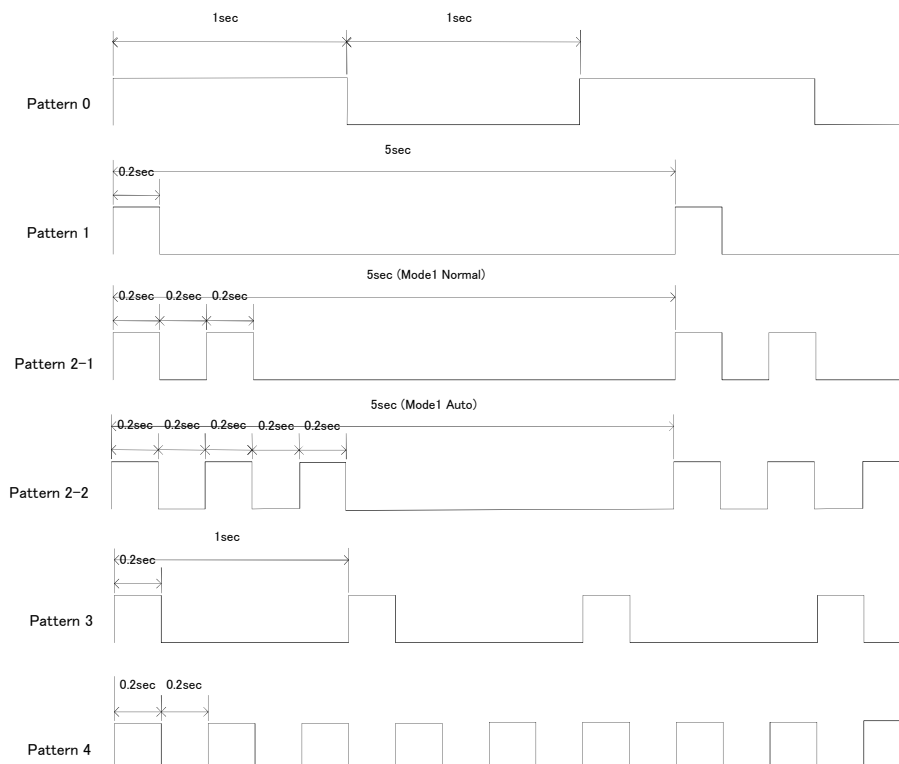


Figure 5.4 LED Blinking Pattern

5.2.3 INITIALIZATION INDICATION FUNCTION

The device enters initialization immediately after power-on/reset, receiving a software reset command, or after exiting CONFIG mode (ATENDCFG/MODE_CTRL) while receiving a write command when in CONFIG mode. Refer to Figure 5.3 for the processing sequence.

For UART

The device will send a response "Init.M-A351<CR><LF>" to the host after initialization ends.

For SPI

The device will assert Data Ready signal after initialization begins, and negates the Data Ready signal after initialization ends.

5.2.4 BIAS CORRECTION FUNCTION

The device includes a bias correction function which allows the user to apply a fixed bias (offset) correction to the acceleration value by user command. The correction value has a range of -32767 to +32767 μ G that is added to the measured acceleration value before output to the host. The host should set the correction value to "0" (initial value) when not using the bias correction function.

5.2.5 OUTPUT UNIT SELECT FUNCTION

The device includes an output unit select function which allows the user to individually select for each axis between 3 output unit types by user command: acceleration (initial value), tilt angle, or tilt angle speed. This individual select function for each axis is available in combined measurement mode. The tilt angle and tilt angle speed are internally calculated from the measured gravitational acceleration value. Please refer to Section 2.3 for a description of the formula for computation.

5.2.6 OPERATION MODE DESCRIPTION

1) Measurement Mode 1

In Measurement Mode 1, the internal measurement circuits are enabled. To enter Measurement Mode 1, the device must be in IDLE mode and the host sends the command UART: "ATMESMD1<CR><LF>", or SPI: MODE_CTRL (0xA5, 0x11).

If the measurement trigger is set to external trigger, the device will send the measured acceleration results on the falling edge of a LOW pulse on the EXT_TRIG pin. The measurement begins after the external trigger and a short measurement latency delay.

If the measurement trigger is set to internal timer, the device will send measured acceleration results at the programmed time interval. The measurement begins immediately after the internal timer trigger event and a short measurement latency delay.

While in Measurement Mode 1, the host can manually request measured acceleration results by sending commands UART: ATREQDAT<CR><LF>, SPI: MODE_CTRL (0xA5, 0x13).

To exit Measurement Mode 1 and move to IDLE mode, the host can send the command UART: ATENDMES<CR><LF>, SPI: MODE_CTRL (0xA5, 0x00).

2) Automatic Measurement Mode

After power on, the device will automatically shift to Measurement Mode 1, if automatic measurement setting is enabled (without the host sending a command to enter Measurement Mode 1). After entering Measurement Mode 1 automatically, the device can accept commands as normal.

3) Configuration Mode

Configuration Mode allows the host to program or read device information / measurement conditions such as internal timers, filter settings, or device manufacturing information. To enter Configuration Mode, the device must be in IDLE mode and the host sends the command UART: "ATCONFIG<CR><LF>", or SPI: MODE_CTRL (0xA5, 0x02).

As an example when in Configuration Mode, if the host sends UART: "ATRDDTRG<CR><LF>" to the device to read the current trigger setting, and the following result is returned "DTRG=2,00005,0<CR><LF>" and "<CR><LF>OK<CR><LF>". The device is currently set for measurement trigger from internal timer with a measurement interval value of 5 ms.

5.3 INTERNAL FILTER

The device has programmable internal FIR filter. The FIR filter setting can be set using the WRFILT command to program the FILTER_CTRL register. This filter uses a Kaiser Window with selectable filter TAP (128, 256, or 512), and cutoff frequencies (f_c =5, 10, 20, 50, or 100Hz). Refer to Figures 5.5, 5.6, 5.7, 5.8, 5.9, and 5.10 to see the typical filter characteristics.

Table 5.2 Internal Filter Cutoff Bandwidth

Parameter	Condition	Min	Typ	Max	Unit
Filter bandwidth	-3dB, 512Tap			121	Hz

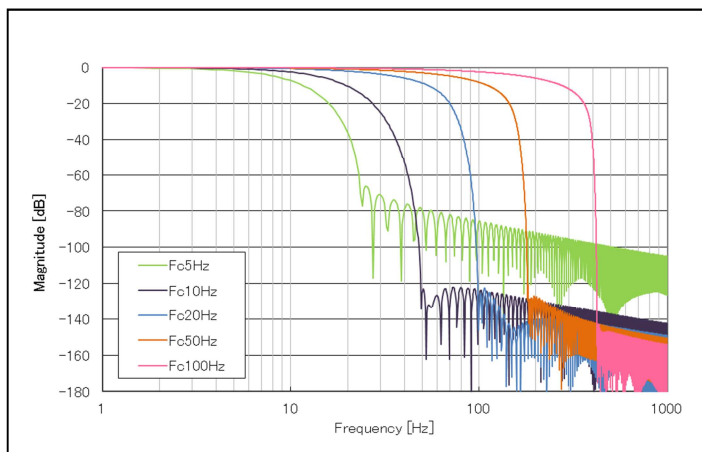


Figure 5.5 FIR Kaiser Filter Characteristic (Tap512)

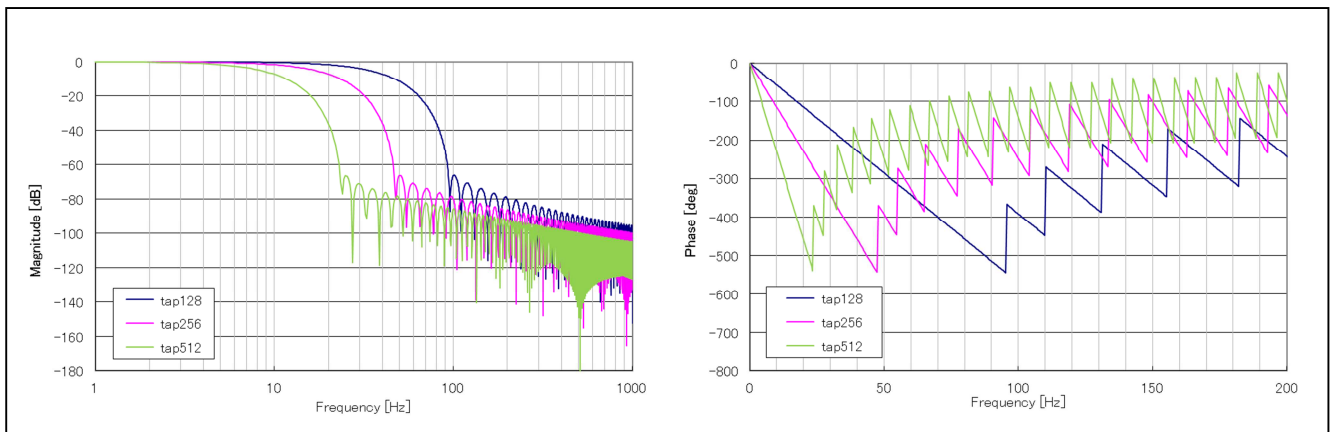


Figure 5.6 FIR Kaiser Filter Characteristic ($F_c=5\text{Hz}$)

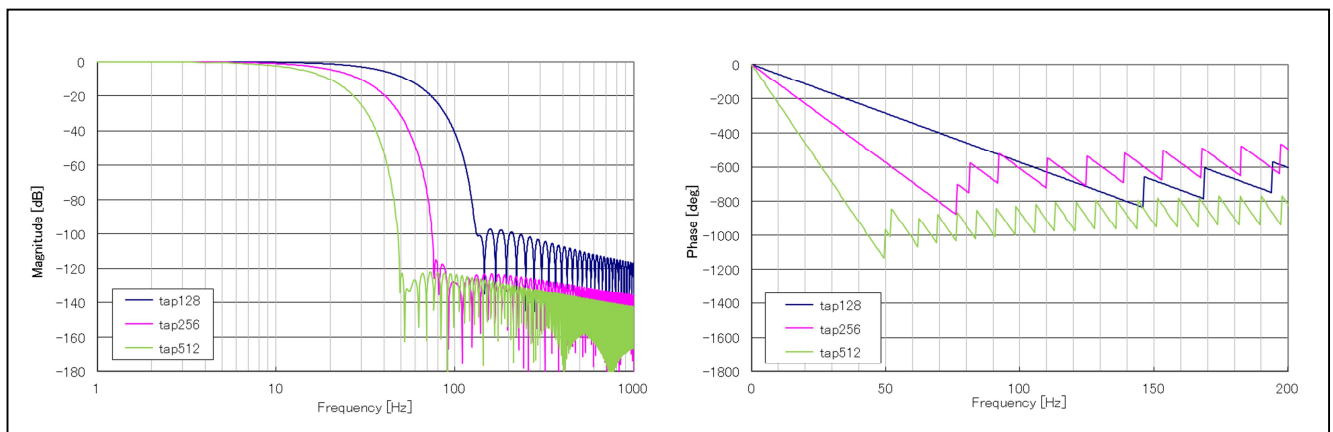


Figure 5.7 FIR Kaiser Filter Characteristic ($F_c=10\text{Hz}$)

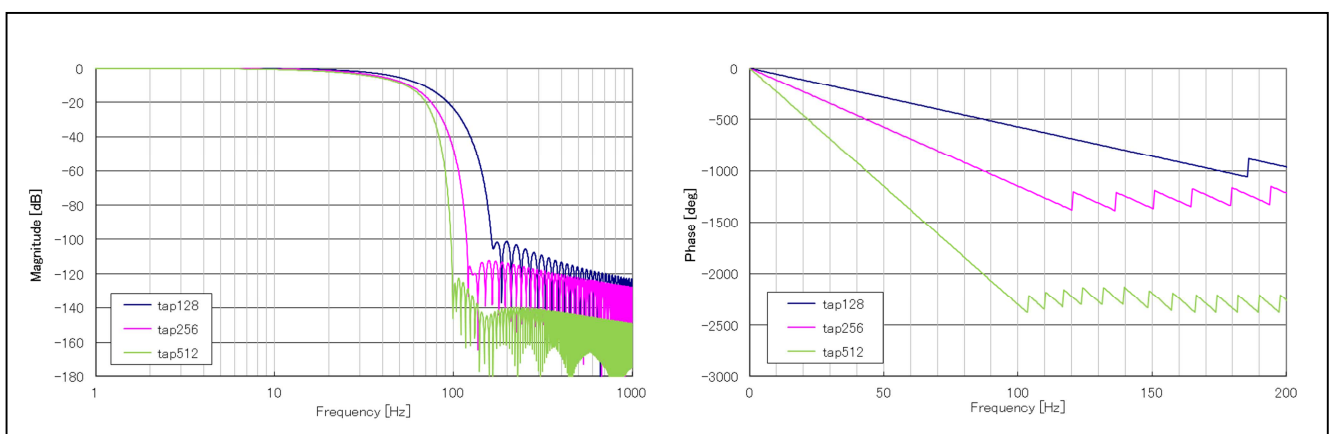


Figure 5.8 FIR Kaiser Filter Characteristic ($F_c=20\text{Hz}$)

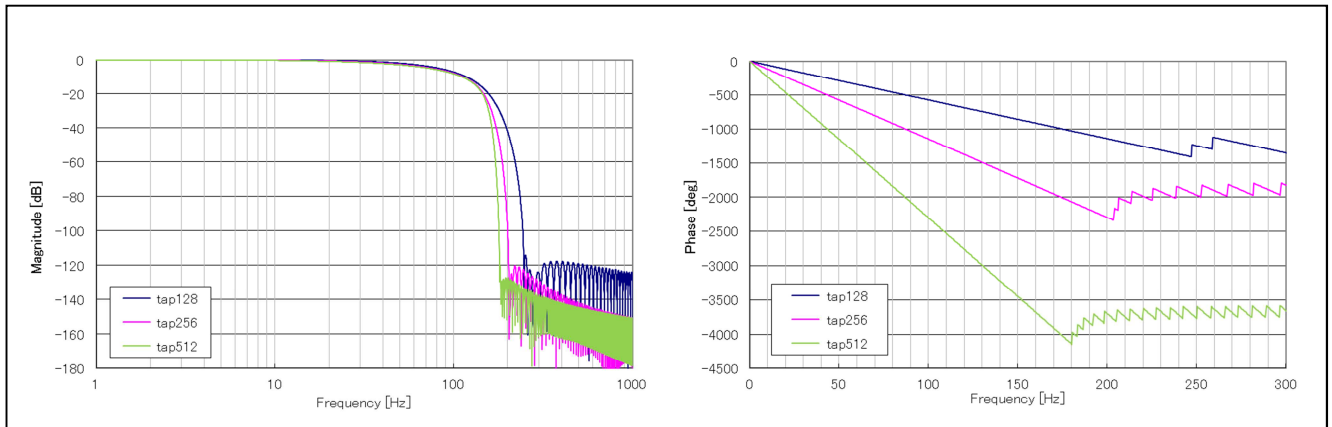


Figure 5.9 FIR Kaiser Filter Characteristic ($F_c=50\text{Hz}$)

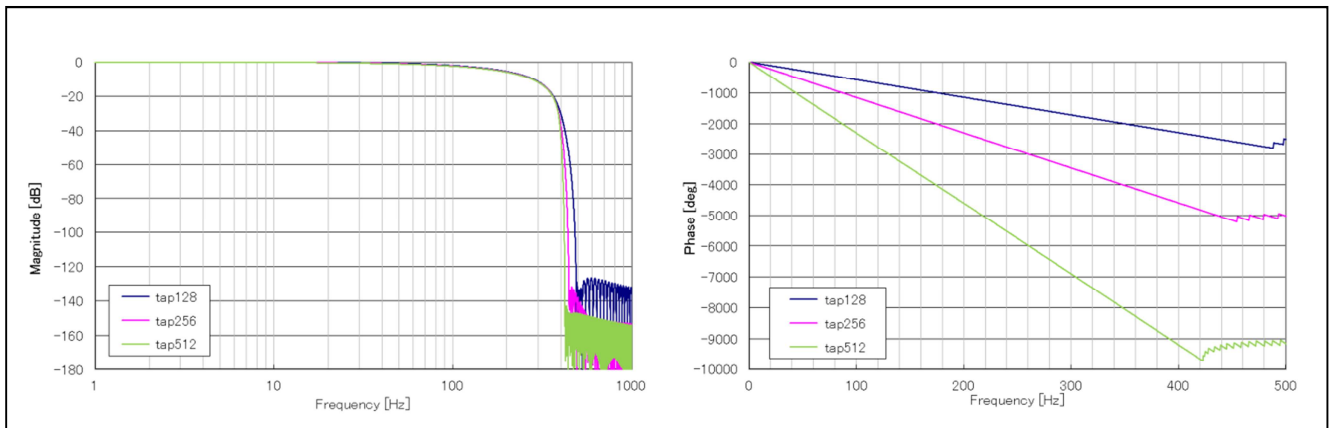


Figure 5.10 FIR Kaiser Filter Characteristic ($F_c=100\text{Hz}$)

The host must set the cutoff frequency of the FIR filter and the output rate in proper combination to avoid aliasing. Only the UART interface version (not SPI interface version) supports an output rate of 1000Sps either by external trigger measurement or internal timer measurement.

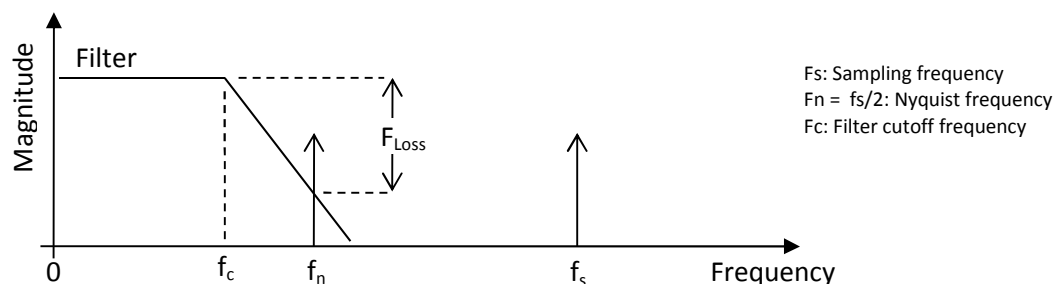


Figure 5.11 Anti-Aliasing Relationship Diagram

Table 5.3 Supported Settings Output Rate and Filter Cutoff Frequency

		Group delay	Output Rate				
			1000Sps	500Sps	200Sps	100Sps	50Sps
Filter 512Tap	100Hz	63.9ms	○	×	×	×	×
	50Hz		○	○	×	×	×
	20Hz		○	○	○	×	×
	10Hz		○	○	○	○	×
	5Hz		△	△	△	△	△
Filter 256Tap	100Hz	31.9ms	○	×	×	×	×
	50Hz		○	○	×	×	×
	20Hz		○	△	×	×	×
	10Hz		○	○	○	×	×
	5Hz		△	△	△	△	×
Filter 128Tap	100Hz	15.9ms	○	×	×	×	×
	50Hz		○	○	×	×	×
	20Hz		△	△	×	×	×
	10Hz		△	△	×	×	×
	5Hz		△	△	△	×	×

○: $F_{Loss} < -120\text{dB}$ Recommended setting

△: $F_{Loss} < -60\text{dB}$ Although a possible setting, some decrease in measurement quality due to aliasing

×: $f_n < f_c$ Invalid setting. When using internal timer measurement, measurement data responds with error "0x64000000".

6. HOST INTERFACE

This device can be ordered with either a UART interface or a SPI interface. Both SPI and UART interfaces have similar functionality.

6.1 UART INTERFACE

6.1.1 UART COMMUNICATION CONDITION

Table 6.1 UART Communication Conditions

Parameter	Supported Values
Transfer Rate	57.6 kbps /115.2kbps/ 230.4kbps/ 460.8kbps (Selectable by command)
Start	1bit
Data	8bit (LSB First)
Stop	1bit/ 2bit (Selectable by command)
Parity	None/ Even/ Odd (Selectable by command)

6.1.2 COMMAND SEQUENCE

This device responds to all commands received from the host with a result code. The host must wait to receive the result code from the previous command before issuing the next command. When the sensor unit is in measurement mode with internal timer triggering, this device keeps sending the sensor data at the user programmed timer interval until the measurement end command is received to go to IDLE mode.

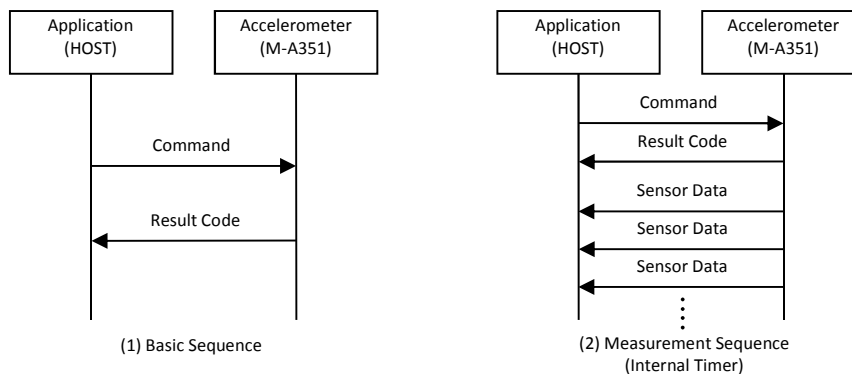


Figure 6.1 Command Sequence

6.1.3 COMMAND DESCRIPTION

The following describes the list of available commands and functions. All commands must be pre-fixed or start with "AT" and terminated or end with "<CR><LF>". All result codes returned from the sensor unit to the host is either:

- "<CR><LF>OK<CR><LF>" to indicate success.
- "<CR><LF>#<CR><LF>" to indicate failure.

1) Available commands in IDLE mode:

Format	MESMD1
Function	Go to Measurement Mode 1.
Explanation	Set device to Measurement Mode 1. When a request for sensor data is triggered, data is transmitted to the host.
Response	<Result> OK (success) # (failure)

Format	CONFIG
Function	Go to Configuration Mode.
Explanation	Set device to CONFIG Mode to allow reading or writing device settings.
Response	<Result> OK (success) # (failure)

2) Available commands in Measurement Mode1:

Format	REQDAT
Function	Request sensor data transmission.
Explanation	The latest measurement data is sent to the host. - The maximum request rate is 500Sps. - Refer to Section 5.3, to ensure the FIR filter is valid according to Table 5.3 Supported Settings Output Rate and Filter Cutoff Frequency to avoid aliasing.
Response	Refer to Section 6.1.4 for the output format of the sensor data.

Format	ENDMES
Function	End Measurement Mode 1.
Explanation	The device stops measurement operation, and goes to IDLE mode.
Response	<Result> OK (success) # (failure)

3) Available commands in Configuration mode:

Format	RDMODL
Function	Read the device model and other device manufacturing information.
Explanation	The device sends model name, date of manufacture, and serial number.
Response	MODL=<Model>,<yymmdd>,<SerNo> <Result> <Model> Model name <yymmdd> Date of manufacture <SerNo> Serial number <Result> OK (success) # (failure) (Example Case) Model Name = M-A351AU Date of Manufacture = October 8, 2014 Serial Number = 12345678 (Device Output) MODL = MA351AU, 141008, 12345678-***** OK

Format	RDFVER
Function	Read the firmware version.
Explanation	The device sends the firmware version number.
Response	FVER=<FVer> <Result> <FVer> firmware version number <Result> OK (success) # (failure) (Example Case) Firmware version number = 1.00 (Device Output) FVER=1.00 OK

	1 ~ 10s: The averaging process uses the sensor data from the entire timer interval. 11 ~ 60s: The averaging process uses the most recent 500 samples of sensor data before the timer interval. NOTE: The measurement interval is limited by the relationship with the UART communication speed. Refer to the restrictions in Note 2 located after the WRUART command description. NOTE: The measurement interval is used to calculate the tilt angular speed regardless of the measurement trigger conditions.
Response	<Result> OK (success) # (failure)

NOTE 1: Averaging Process Output When Timer is Measured in Unit [s] Seconds

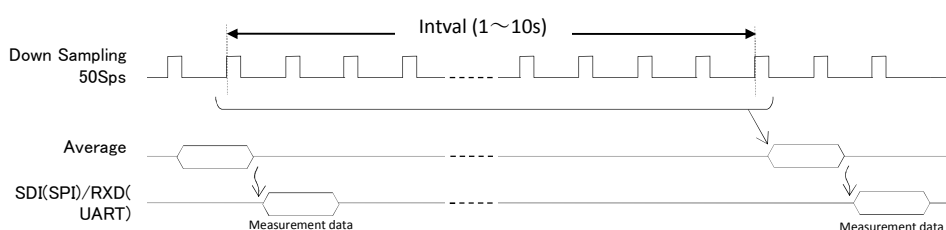


Figure 6.2 Averaging Process Output When Timer Interval is 1-10s

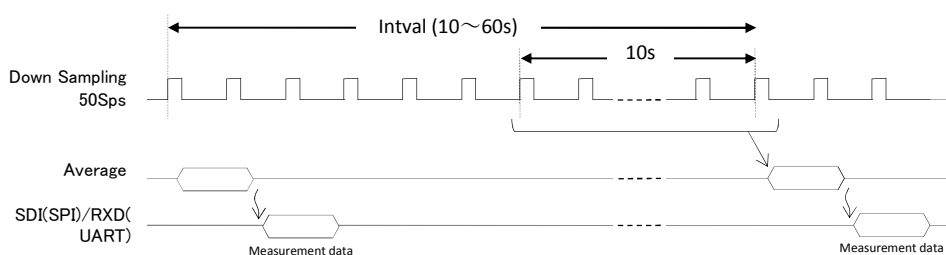


Figure 6.3 Average Process Output When Timer Interval is 10-60s

Format	RDUART
Function	Read the device UART setting.
Explanation	The device sends the UART setting (baud rate, parity bit, and stop bit).
Response	UART=<BaudRate>,<ParityBit>,<Stop> <Result> <BaudRate> Transmission rate 57600 (57.6kbsp) 115200 (115.2kbsp) 230400 (230.4kbsp) 460800 (460.8kbsp) <ParityBit> Parity bit N (None) E (Even) O (Odd) <Stop> Stop bit 1 (one bit) 2 (two bits) <Result> OK (success) # (failure)

Format	WRUART=<BaudRate>,<ParityBit>,<Stop>
Function	Write the setting for UART transmission.
Explanation	The host writes the specified parameters <BaudRate>, <ParityBit>, and <Stop> . <BaudRate> Transmission rate 57600 (57.6kbsp) 115200 (115.2kbsp) 230400 (230.4kbsp) 460800 (460.8kbsp) <ParityBit> Parity bit N (None) E (Even) O (Odd) <Stop> Stop bit 1 (one bit) 2 (two bits) NOTE: These UART settings take effect after receiving the "ENDCFG" command to exit Configuration Mode.
Response	<Result> OK (success) # (failure)

NOTE 2: Sensor Data Transmission Cycle and UART Transmission Rate

The time required to transmit is different according to the number of output axes and the UART transmission rate. Please set it referring to Table 6.2 when you decide the transmission rate.

Table 6.2 UART Baud Rate and Sensor Data Transmission Cycle

Transmission Rate (bps)	Minimum Measurement Interval (msec)
57600	10
115200	5
230400	2
460800	1

Based on UART transmission setting:

Stop bit =1, Parity =None

Based on output condition:

Outputs three axes, and temperature

Format	ENDCFG
Function	End Configuration mode.
Explanation	The device exits Configuration mode. While in CONFIG mode, if any "WR****" commands were received before the ENDCFG command, the device will write the settings to non-volatile memory, perform an internal initialization, and go to IDLE mode. If no "WR*****" command was received, the device goes immediately to IDLE mode.
Response	<Result> OK (success) # (failure)

Format	TSTSLF														
Function	Initiate a self-diagnosis test, and send the result.														
Explanation	The device performs a self-diagnosis test and the results are sent. The following diagnostic outcomes are sent for each test. Refer to Note 3 for description of the self-diagnostic tests. <table border="1"> <thead> <tr> <th>Test Number</th><th>Self-diagnosis Test Description</th></tr> </thead> <tbody> <tr> <td>1</td><td>Power-supply voltage</td></tr> <tr> <td>2</td><td>Non-volatile RAM</td></tr> <tr> <td>3</td><td>Reference clock</td></tr> <tr> <td>4</td><td>Acceleration sensor</td></tr> <tr> <td>5</td><td>Temperature sensor</td></tr> <tr> <td>6</td><td>Built-in RAM (Only at startup)</td></tr> </tbody> </table>	Test Number	Self-diagnosis Test Description	1	Power-supply voltage	2	Non-volatile RAM	3	Reference clock	4	Acceleration sensor	5	Temperature sensor	6	Built-in RAM (Only at startup)
Test Number	Self-diagnosis Test Description														
1	Power-supply voltage														
2	Non-volatile RAM														
3	Reference clock														
4	Acceleration sensor														
5	Temperature sensor														
6	Built-in RAM (Only at startup)														
Response	<Result> "Judgement" + "Test number" Judgement: OK = "O" and NG = "N" (Example) "O3" means no error was detected during the Reference clock test "N4" means an error was detected during the Acceleration sensor test														

NOTE 3: Self-diagnosis Test Description

The following describes the details of the self-diagnosis tests.

1. Power-supply voltage

The result of the self test on the power-supply voltage is shown. The power-supply voltage is confirmed to be approximately within the range of 3.0~3.6V.

2. Non-volatile RAM

The result of a self test on the non-volatile RAM(EEPROM) is shown. The checksum result of data in non-volatile RAM is confirmed to be correct.

3. Reference clock

The result of the self test on the 32.768kHz & 32MHz oscillator is shown. The frequency of 32MHz is compared relative to the 32.768kHz quartz oscillator for frequency tolerance within ± 400 ppm.

4. Acceleration sensor

The result of the self test of the acceleration sensor is shown. The synthesized value of the acceleration sensor vector for the X, Y, and Z axis under the static conditions is confirmed to be approximately in the range of 0.8~1.2G.

5. Temperature sensor

The result of the self test on the temperature sensor is shown.

6. Built-in RAM

The result of the self test on the built-in RAM is shown. A write and read verification of RAM is confirmed. This test is only performed at device startup.

Format	RDAUTO
Function	Read the status of automatic measurement mode.
Explanation	The device sends the status of automatic measurement mode (enters measurement mode automatically after power on).
Response	AUTO=<Auto> <Result> <Auto> Automatic measurement mode is ON OFF

Format	WRAUTO=<Auto>
Function	Write the setting to enable/disable automatic measurement mode.
Explanation	The host writes to enable or disable entering measurement mode automatically after power supply starts by specifying the parameter <Auto>. <Auto> Automatic Measurement mode is ON OFF
Response	<Result> OK (success) # (failure)

Format	RDBIAS
Function	Read the bias correction value.
Explanation	The device sends the value of the bias correction for each axis.
Response	BIAS=<X_Bias>,<Y_Bias>,<Z_Bias> <Result> < X_Bias> X axis bias correction value -32767 ~ 32767 (unit=uG) < Y_Bias> Y axis bias correction value -32767 ~ 32767 (unit=uG) < Z_Bias> Z axis bias correction value -32767 ~ 32767 (unit=uG)

Format	WRBIAS=<X_Bias>,<Y_Bias>,<Z_Bias>
Function	Write the setting of the bias correction value.
Explanation	The host writes the bias correction value that will be applied to the sensor measurement value for each axis by specifying the parameter <*_ Bias >. < X_Bias> X axis bias correction value -32767 ~ 32767 (unit=uG) < Y_Bias> Y axis bias correction value -32767 ~ 32767 (unit=uG) < Z_Bias> Z axis bias correction value -32767 ~ 32767 (unit=uG)
Response	<Result> OK (success) # (failure)

6.1.4 COMMAND FORMAT

The output data of the measurement value is in binary format, whereas all other command controls and responses are in ASCII format.

1) Command Format

The commands messages sent to the device starts with "AT" header and ends with a "<CR><LF>" trailer. The command and parameter is separated with an "=" (equal sign). In the case the command includes two or more parameters, the parameters are separated with a "," (comma) delimiter.

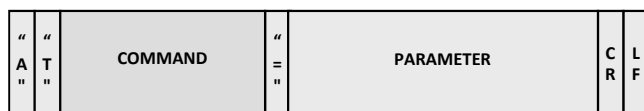


Figure 6.4 Command Format

2) Result Code

Return Value: "OK (command success)" or "# (command failure)"

The result code is sent by the device in response to commands starts and ends with a "<CR><LF>".

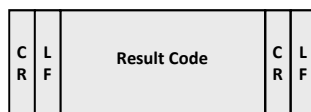


Figure 6.5 Result Code

3) Result Data

Return Value: Responses that do not contain "OK" or "#"

① Excluding Measurement Value

The device responds to a command with result data followed by a "<CR><LF>" placed at the end.

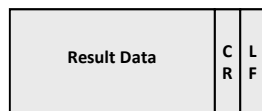


Figure 6.6 Result Data

② Measurement Value

Tables 6.3 and 6.4 show the output data packet format for the measurement values. The measurement values (acceleration, tilt angle, tilt angle speed, and temperature) are in binary format. The host should set the desired physical output value, axis, and temperature configuration by using the WRDFRM and the WRPYCL command.

Table 6.3 UART Data Packet Format Example 1

Case: WRDFRM=0, 1, XYZ (output acceleration, temperature, and X+Y+Z axis).

Byte No.	Name	Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0
1	ADDRESS	ADDRESS[7:0]							
2	DATA_LENGTH	DATA_LENGTH[7:0]							
3	XACCD_3	XACCD_OUT3 [31:24]							
4	XACCD_2	XACCD_OUT2 [23:16]							
5	XACCD_1	XACCD_OUT1 [15:8]							
6	XACCD_0	XACCD_OUT0 [7:0]							
7	YACCD_3	YACCD_OUT3 [31:24]							
8	YACCD_2	YACCD_OUT2 [23:16]							
9	YACCD_1	YACCD_OUT1 [15:8]							
10	YACCD_0	YACCD_OUT0 [7:0]							
11	ZACCD_3	ZACCD_OUT3 [31:24]							
12	ZACCD_2	ZACCD_OUT2 [23:16]							
13	ZACCD_1	ZACCD_OUT1 [15:8]							
14	ZACCD_0	ZACCD_OUT0 [7:0]							
15	TEMP_2	TEMP_OUT2 [23:16]							
16	TEMP_1	TEMP_OUT1 [15:8]							
17	TEMP_0	TEMP_OUT0 [7:0]							
18	CHECKSUM	CHECKSUM [7:0]							
19	CR	0x0D							
20	LF	0x0A							

Three axis acceleration data, internal temperature, sensor data of X, Y, and Z are sent.

The UART data packet format is decoded as follows:

ADDRESS

Determines the measurement output format type

Acceleration: 0x80 , Tilt angle: 0x81, Tilt angle speed: 0x82, Combined output: 0x83

DATA_LENGTH

Data length of the entire data packet including <CR><LF>

Data length: 20 bytes in this example

*ACCD *

Measurement data

(1)Acceleration

Unit : G

Two's complement and four byte fixed zero point

bit31 : Sign part

bit30-24 : Integer part

bit23-0: Fraction part

NOTE: 0x63000000(+99G) is output when the maximum value of the range of detection is exceeded, and 0x9D000000(-99G) is output when the minimum value is exceeded.

(2)Tilt angle

Unit :Radian

Two 's complement and four byte fixed zero point

bit31 : Sign part

bit30-29 : Integer part

bit28-0 : Fraction part

NOTE: 0x374AC286(+99°) is output when the maximum value of the range of detection is exceeded, and 0xC8B53D7A(-99°) is output when minimum value is exceeded.

(3)Tilt angle speed

Unit :Radian per measurement interval

Radian/s in case of unit [s] seconds

Radian/ms in case of unit [ms] milliseconds

Two 's complement and four byte fixed zero point

bit31 : Sign part

bit30-29 : Integer part

bit28-0 : Fraction part

NOTE: 0x374AC286(+99°) is output when the maximum value of the range of detection is exceeded, and 0xC8B53D7A(-99°) is output when minimum value is exceeded.

TEMP

Thermal data

Unit : °C

Two's complement and three byte fixed zero point

bit23 : Sign part

bit22-10 : Integer part

bit9-0 : Fraction part

NOTE: This reference is used for internal temperature correction, and is not guaranteed for accuracy of the absolute internal temperature.

CHECKSUM

Checksum data

The checksum range of data packet is calculated from the end of the address byte up to start of the checksum byte. The computational method of checksum simply adds the object data in 8bit (bytes) units, and places the resulting 8-bit sum as checksum data.

For example: Because the sum total is "672" when the response data is "14 00 03 1A E5 FF FF D3 E0 01 00 12 F3 00 70 35", checksum becomes "72".

Table 6.4 UART Data Packet Format Example 2

Case: WRDFRM=1,0,Y (Tilt angle, no temperature, and Y axis output)

Byte No.	Name	Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0
1	ADDRESS	ADDRESS[7:0]							
2	DATA_LENGTH	DATA_LENGTH[7:0]							
3	YANGD_3	YANGD_OUT3 [31:24]							
4	YANGD_2	YANGD_OUT2 [23:16]							
5	YANGD_1	YANGD_OUT1 [15:8]							
6	YANGD_0	YANGD_OUT0 [7:0]							
7	CHECKSUM	CHECKSUM [7:0]							
8	CR	0x0D							
9	LF	0x0A							

Y tilt angle degree data is sent.

Please refer to the description after Table 6.3 for decoding the UART data packet format.

6.2 SPI INTERFACE

The SPI version of this device operates in SPI Slave Mode, and is controlled by accessing the control registers. The numerical data format of the commands and responses are all in binary.

6.2.1 SPI SPECIFICATIONS

Table 6.5 SPI Communication Condition

Parameter	Setting
Mode	Slave
Word length	8 bits
Phase	Rising Edge
Polarity	Negative Logic

Refer to Section 2.5 for details of the SPI timing specification.

6.2.2 SPI READ TIMING

The responses to read commands are always returned as 8-bit data (i.e. reading data from internal registers). The response to the read command is transmitted on the same cycle as the next following command cycle. The host must ensure to meet the T_{stall} wait time between each read command cycle as specified in Section 2.5 SPI timing specifications and Figure 6.7.

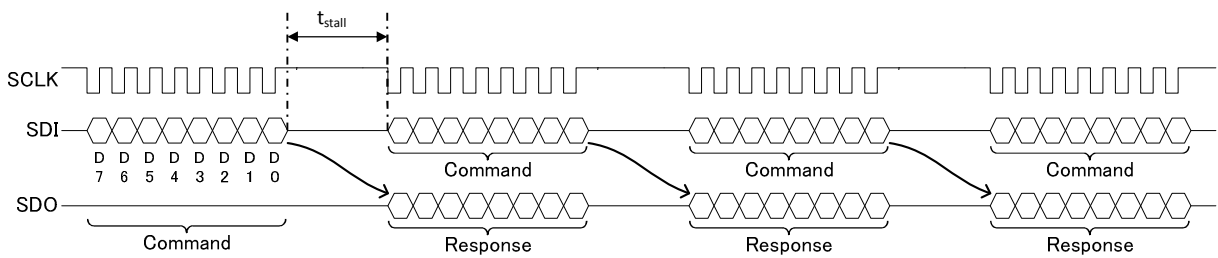


Figure 6.7 SPI Read Timing

Table 6.6 Command Format (Read Address)

7	6	5	4	3	2	1	0
0	A[6:0]						

A[6:0] ... Register Address

Table 6.7 Response Format (Read Data)

7	6	5	4	3	2	1	0
D[7:0]							

D[7:0] ... Register Read Data

6.2.3 SPI WRITE TIMING

The register write command is always 8-bits and has no response. The host must ensure to meet the T_{stall} and t_{WEXE} wait processing time in between SPI cycles as per Section 2.5 for detailed SPI timing specifications and Figure 6.8.

NOTE: Refer to Figure 2.2 for timing requirement when rebooting the device by MODE_CTRL.

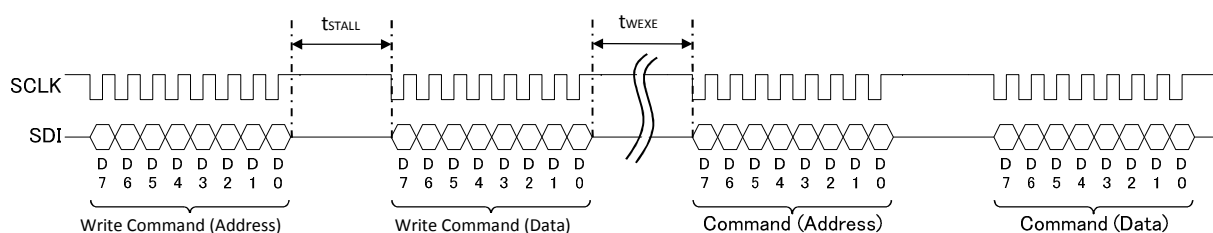


Figure 6.8 SPI Write Timing

Table 6.8 Command Format (Write Address)

7	6	5	4	3	2	1	0
1	A[6:0]						

A[6:0] ... Register Address

Table 6.9 Command Format (Write Data)

7	6	5	4	3	2	1	0
D[7:0]							

D[7:0] ... Register Write Data

6.2.4 DATA READY SIGNAL

The Data Ready signal is asserted and driven HIGH when a complete set of sensor samples has processed, and the registers have been updated with the latest sensor values. After the sensor value is read by the host, and the ReadEND command (Register Address: 0x7F) is received, the Data Ready signal is negated and driven LOW. Figure 6.9, Figure 6.10, and Figure 6.11 are timing diagrams showing examples of the Data Ready under different conditions.

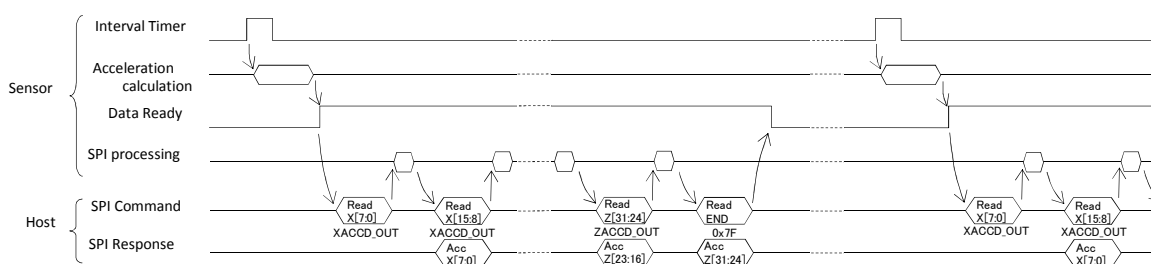


Figure 6.9 Data Ready Timing 1 (Timer Interval Measurement)

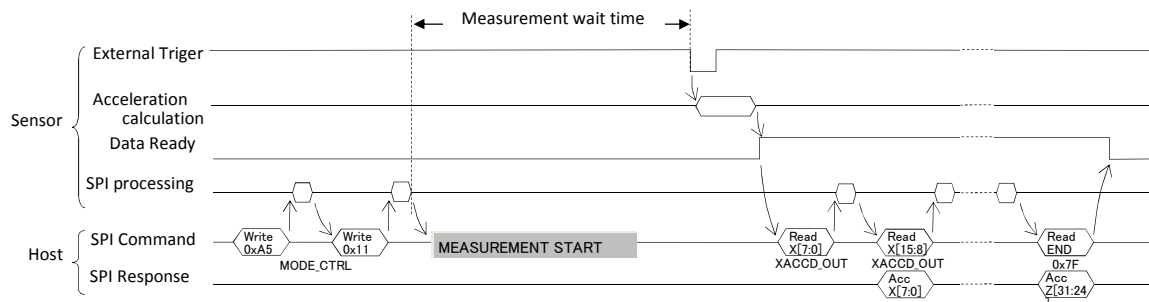


Figure 6.10 Data Ready Timing 2 (Measurement Start or External Trigger)

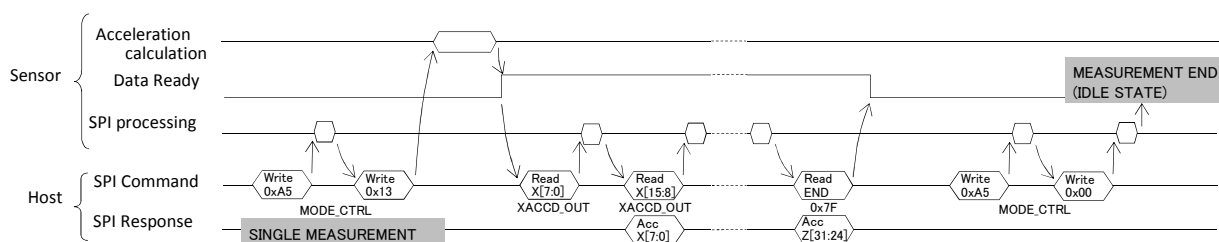


Figure 6.11 Data Ready Timing 3 (Single Shot Measurement and Measurement End)

NOTE:

- When measurement trigger status is already set when the next measurement process is started, the trigger status is maintained. When the Data Ready signal is negated by ReadEND command after the trigger status for the next measurement process has already started, the trigger status will be cleared.
- The host must not send ReadEND command (0x7F) except for the purpose of ending the reading of sensor data.

6.2.5 USER REGISTER

The SPI interface version of this product is controlled by accessing control registers as listed in Table 6.10 Register Map. The initial values of the control registers after internal initialization are the values indicated in "Default" column. The registers that show a "○" in "NVRAM Backup" column allows the user to preserve the register value, so that the initial value of the register is retrieved from non-volatile memory immediately after turning on the power supply. The registers can only be accessed when the device is in the mode specified in the "MODE" column. Refer to Figure 5.3 State Transition Diagram for a description on transitioning between the operation modes. The host must not attempt to access a register outside of its supported operation mode.

Details of each register are shown in Section 6.2.5.1 ~ Section 6.2.5.12. A "-" symbol in the register bit field means the bit is reserved. Write a "0" to reserved bits during a write accesses. During a read accesses, a reserved bit can return either "0" or "1". Writing to a read-only register is prohibited.

Table 6.10 Register Map

Name	R/W	MODE	Address	Default	NVRAM Backup	Function
XACCD_OUT	R	Measurement	0x00-0x03	-		Acceleration Sensor X Axis Value
YACCD_OUT	R	Measurement	0x04-0x07	-		Acceleration Sensor Y Axis Value
ZACCD_OUT	R	Measurement	0x08-0x0B	-		Acceleration Sensor Z Axis Value
TRIGR_CTRL	R/W	Config	0x20	0x20	○	Data Output Trigger Control
INTVL TIME	R/W	Config	0x21	0x05	○	Timer Interval Value
MSC_CTRL	R/W	Config	0x23	0x00	○	Sensor type Control
PYCL_CTRL	R/W	Config	0x24	0x05	○	Physical Output Control
MODE_CTRL	R/W	ALL	0x25	0x00		Operation Mode Control
FILTER_CTRL	R/W	Config	0x28	0x65	○	Internal Filter Control
TEMP_OUT	R	Measurement	0x29-0x2B	-		Internal Temperature Sensor Value
MODEL_READ	R	Config	0x30-0x50	-		Read Product Information
SLFTTEST_READ	R	Config	0x51	-		Read Self-diagnosis Results
BIAS_CTRL	R/W	Config	0x52-0x57	0x00	○	Bias Correction Control
RESET_CTRL	R/W	ALL	0x60	0x00		Software Reset

6.2.5.1 ACCD_OUT Register

Addr (Hex)	Bit31	...	Bit0	R/W
03-00h	XACCD_OUT			R
07-04h	YACCD_OUT			R
0B-08h	ZACCD_OUT			R

bit[31:0] Acceleration Sensor Output

Returns the acceleration/tilt angle/tilt angle speed data of the 3 axes. The output format type must be set in the MSC_CTRL register, and for compound measurement mode, the physical output type must be set in the PYCL_CTRL register. The sensor axis output is 32-bit little endian with the most significant byte in the upper address, and least significant byte in the lower order address.

(1)Acceleration

Unit : G

Two's complement and four byte fixed zero point

bit31 : Sign part

bit30-24 : Integer part

bit23-0 : Fraction part

NOTE: 0x63000000(+99G) is output when the maximum value of the range of detection is exceeded, and 0x9D000000(-99G) is output when the minimum value is exceeded.

(2)Tilt angle

Unit : Radian

Two's complement and four byte fixed zero point

bit31 : Sign part

bit30-29 : Integer part

bit28-0 : Fraction part

NOTE: 0x374AC286(+99°) is output when the maximum value of the range of detection is exceeded, and 0xC8B53D7A(-99°) is output when minimum value is exceeded.

(3)Tilt angle speed

Unit : Radian per measurement interval

Radian/s in case of unit [s] seconds

Radian/ms in case of unit [ms] milliseconds

Two's complement and four byte fixed zero point

bit31 : Sign part

bit30-29 : Integer part

bit28-0 : Fraction part

NOTE: 0x374AC286(+99°) is output when the maximum value of the range of detection is exceeded, and 0xC8B53D7A(-99°) is output when minimum value is exceeded.

6.2.5.2 TRIGR_CTRL Register

Addr (Hex)	Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0	R/W
20h	-	-	IVLTIM_CTRL	EXTTRG_CTRL	-	-	-	TIME UNIT	R/W

bit[5] IVLTIM_CTRL

Enables or disables the timer interval function for triggering a measurement operation at the specified cycle time.

1 : Enable

0 : Disable

bit[4] EXTTRG_CTRL

Enables or disables the external trigger input (EXT_TRG) for triggering a measurement operation.

1 : Enable

0 : Disable

bit[0] TIME UNIT

This bit specifies the unit of the time for the timer interval specified with INTVL TIME.

1 : Second [s]

0 : Millisecond [ms]

6.2.5.3 INTVL_TIME Register

Addr (Hex)	Bit7	...	Bit0	R/W
21h	INTVL TIME			R/W

bit[15:0] INTVL_TIME

This register is used with the TIME UNIT bit in TRIGR_CTRL register to specify the timer value of interval timer.

1) For TIME UNIT = [s]

The value must be set within the valid range below.

INTVL TIME = 1s ~ 60s

2) For TIME UNIT = [ms]

The value must be set to one of valid settings below.

INTVL TIME = 2ms : 500Sps

5ms : 200Sps

10ms : 100Sps

20ms : 50Sps

- Refer to Section 5.3, to ensure the FIR filter setting is valid according to Table 5.3 Supported Settings Output Rate and Filter Cutoff Frequency to avoid aliasing.

- When the Time unit is [s] seconds, the device internally downsamples to 50Sps (512Tap), and performs the following averaging process depending on the measurement interval setting, except in the case when timer measurement will output the latest value without averaging as in Section 6.1 Note 1.

1 ~ 10s: The averaging process uses the sensor data from the entire timer interval.

11 ~ 60s: The averaging process uses the most recent 500 samples of sensor data before the timer interval.

NOTE: The measurement operation doesn't begin when the INTVL TIME value is invalid.

NOTE: The measurement interval is used to calculate the tilt angular speed regardless of the measurement trigger conditions.

6.2.5.4 MSC_CTRL Register

Addr (Hex)	Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0	R/W
23h	SELF_TEST	-	-	-	-	AUTO_MES	MODEL_TYPE		R/W

bit[7] SELF_TEST

Writing a 1 to this bit initiates a self test and stays 1 during execution. This bit returns to 0 upon completion. The host should confirm this bit returns to 0, before checking the results in SLFTEST_READ Register.

bit[2] AUTO_MES

This bit selects if the device automatically goes to Measurement Mode 1 after power-on.

1 : Automatic measuring system ON

0 : Automatic measuring system OFF

bit[1:0] MODEL_TYPE

These bits select the sensor measurement output type.

00 : Accelerometer

01 : Tilt angle

10 : Tilt angle speed

11 : Compound measurement

6.2.5.5 PYCL_CTRL Register

Addr (Hex)	Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0	R/W
24h	-	-	Z_PHYQ		Y_PHYQ		X_PHYQ		R/W

bit[5:4] Z_PHYQ

These bits select the physical output type for the Z axis.

00 : Acceleration

01 : Tilt angle

10 : Tilt angle speed

bit[3:2] Y_PHYQ

These bits select the physical output type for the Y axis.

00 : Acceleration

01 : Tilt angle

10 : Tilt angle speed

bit[1:0] X_PHYQ

These bits select the physical output type for the X axis.

00 : Acceleration

01 : Tilt angle

10 : Tilt angle speed

NOTE: This register only has effect when compound measurement is enabled.

6.2.5.6 MODE_CTRL Register

Addr (Hex)	Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0	R/W
25h	-	-	-	MES_MOD	MODE_STAT		MODE_CMD		R/W *1

*1 : MODE_STAT is reading-only.

bit[4] MES_MOD

This bit sets the type of measurement mode. The measurement mode is must be set to Mode 1.

1 : Mode 1 (fixed)

0 : Reserved

This bit is only effective when shifting to measurement mode from idle mode.

This bit automatically returns to "0" after shifting to measurement mode from idle mode.

bit[3:2] MODE_STAT

These read-only status bits display the present operational mode.

00 : Idle mode

01 : Measurement mode

10 : Config mode

11 : Single trigger measurement

bit[1:0] MODE_CMD

Writing to these bits shifts the operation mode to the specified mode. When the operation has completed these bits automatically returns to "00".

00 : Go to IDLE mode

01 : Go to Measurement mode.

10: Go to Config mode.

11: Single trigger measurement

- Refer to the Figure 5.3 State Transition Diagram for valid transitions between different operation modes.

NOTE: When shifting between operation modes sequentially, read the MODE_STAT bits to confirm the operation completed before issuing the next operation mode shift.

NOTE: The minimum period and the setting to avoid aliasing of the single trigger measurement is equal to the timer interval cycle.

6.2.5.7 FILTER_CTRL Register

Addr (Hex)	Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0	R/W
28h	FILTER_TAP				FILTER_FC			FILTER_TY P	R/W

bit[7:4] FILTER_TAP

These bits set the number of taps for the internal FIR filters.

0100 : 128

0101 : 256

0110 : 512

bit[3:1] FILTER_FC

These bits set the cutoff frequency of the FIR Kaiser filter.

000 : 5Hz

001 : 10Hz

010 : 20Hz

011 : 50Hz

100 : Reserved

bit[0] FILTER_TYP

This bit sets the type of FIR filter. The type of filter must be set to FIR Kaiser Filter.

- 1 : FIR Kaiser Filter (fixed)
- 0 : Reserved

NOTE: When an invalid value is written to this register, it is not updated and ignored.

NOTE: Refer to Section 5.3, to ensure the FIR filter setting is valid according to Table 5.3 Supported Settings Output Rate and Filter Cutoff Frequency to avoid aliasing.

6.2.5.8 TEMP_OUT Register

Addr (Hex)	Bit23	...	Bit0	R/W
2B-29h	TEMP OUT			R

bit[23:0] TEMP OUT

These register return the temperature sensor output data. The addressing is little-endian with the low-ranking byte in the lower address, and the high-ranking byte in the upper address.

The read data format is as follows.

- Unit : °C
- Two's complement and three byte fixed zero point
- bit23 : Sign part
- bit22-10 : Integer part
- bit9-0 : Fraction part

NOTE: This register is used for internal temperature correction, and is not guaranteed for accuracy of the absolute internal temperature .

6.2.5.9 MODEL_READ Register

Addr (Hex)	Bit55	...	Bit0	R/W
36-30h	Model Name			R

bit[55:0] Model Name

These registers return the model name of the device. The byte order is little endian with the lower byte in the lower address, and the most significant byte in the upper address. The data output format is ASCII with a total size of 7 bytes or 7 ASCII characters.

Addr (Hex)	Bit47	...	Bit0	R/W
3C-37h	Date of Manufacture			R

bit[47:0] Date of Manufacture

These registers return the Date of Manufacture of the device. The byte order is little endian with the lower byte in the lower address, and the most significant byte in the upper address. The data output format is ASCII with a total size of 6 bytes or 6 ASCII characters.

Addr (Hex)	Bit127	...	Bit0	R/W
4C-3Dh	Serial No			R

bit[127:0] Serial No

These registers return the Serial Number of the device. The byte order is little endian with the most significant byte in the upper address. The data output format is ASCII with a total size of 16 bytes or 16 ASCII characters.

Addr (Hex)	Bit31	...	Bit0	R/W
50-4Dh	Firmware Version			R

bit[31:0] Firmware Version

These registers return the Firmware Version of the device. The byte order is little endian with the most significant byte in the upper address. The data output format is ASCII with a total size of 4 bytes or 4 ASCII characters.

6.2.5.10 SLFTEST_READ Register

Addr (Hex)	Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0	R/W
51h	IRAM	TMP	-	-	ACC	CLK	NVRAM	VDD	R

This register returns the results of the self-diagnosis test when initiated in MSC_CTRL Register.

bit[7] IRAM

This bit returns the result of the self test for the internal RAM. This test is only performed at device startup to confirm writing and reading operation is normal.

0 : Normal

1 : Failure

bit[6] TMP

This bit returns the result of the self test for the temperature sensor used for temperature correction.

0 : Normal

1 : Failure

bit[3] ACC

This bit returns the result of the self test for the acceleration sensor. The synthesized acceleration vector for the X, Y, and Z axis under static conditions is confirmed to be within approximately 0.8~1.2G.

0 : Normal

1 : Failure

bit[2] CLK

This bit returns the result of the self test for 32.768kHz quartz oscillator for the control IC and 32MHz. The frequency of the 32MHz is compared relative to the 32.768kHz quartz oscillator for frequency tolerance to be within ± 400 ppm.

0 : Normal

1 : Failure

bit[1] NVRAM

This bit returns the result of the self test for the non-volatile RAM. The test confirms the result of the checksum.

0 : Normal

1 : Failure

bit[0] VDD

This bit returns the result of the self test for the power supply voltage. The test confirms the power supply voltage is within approximately 3.0-3.6V.

0 : Normal

1 : Failure

6.2.5.11 BIAS_CTRL Register

Addr (Hex)	Bit15	...	Bit0	R/W
53-52h	BIAS_CAL_X			R/W
55-54h	BIAS_CAL_Y			R/W
57-56h	BIAS_CAL_Z			R/W

bit[15:0] Bias correction data

These registers add a bias correction value to the measured sensor value. The byte order is little endian with the most significant byte in the upper address

Two's complement and two byte integer

bit15 : Sign part

bit14-0 : Integer part

Setting range : -32767 ~ 32767 (unit=uG)

6.2.5.12 RESET_CTRL Register

Addr (Hex)	Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0	R/W
60h	-	-	-	-	-	-	-	SOFT _RST	R/W

bit[0] SOFT_RST

Write "1" to execute software reset. After the software reset is completed, the bit automatically goes back to "0".

6.2.6 IMPORTANT NOTE FOR SPI USAGE

The terminal SPI_/SS must be driven HIGH and no communication must occur on the SPI interface during device initialization immediately after the power supply is turned on. The host must begin register access only after initialization has completed. To confirm the device initialization has completed refer to the procedure described in Section 5.2.3.

6.2.7 REGISTER CONTROL EXAMPLE

Figure 6.12 and Figure 6.13 shows an example of device operation using registers.

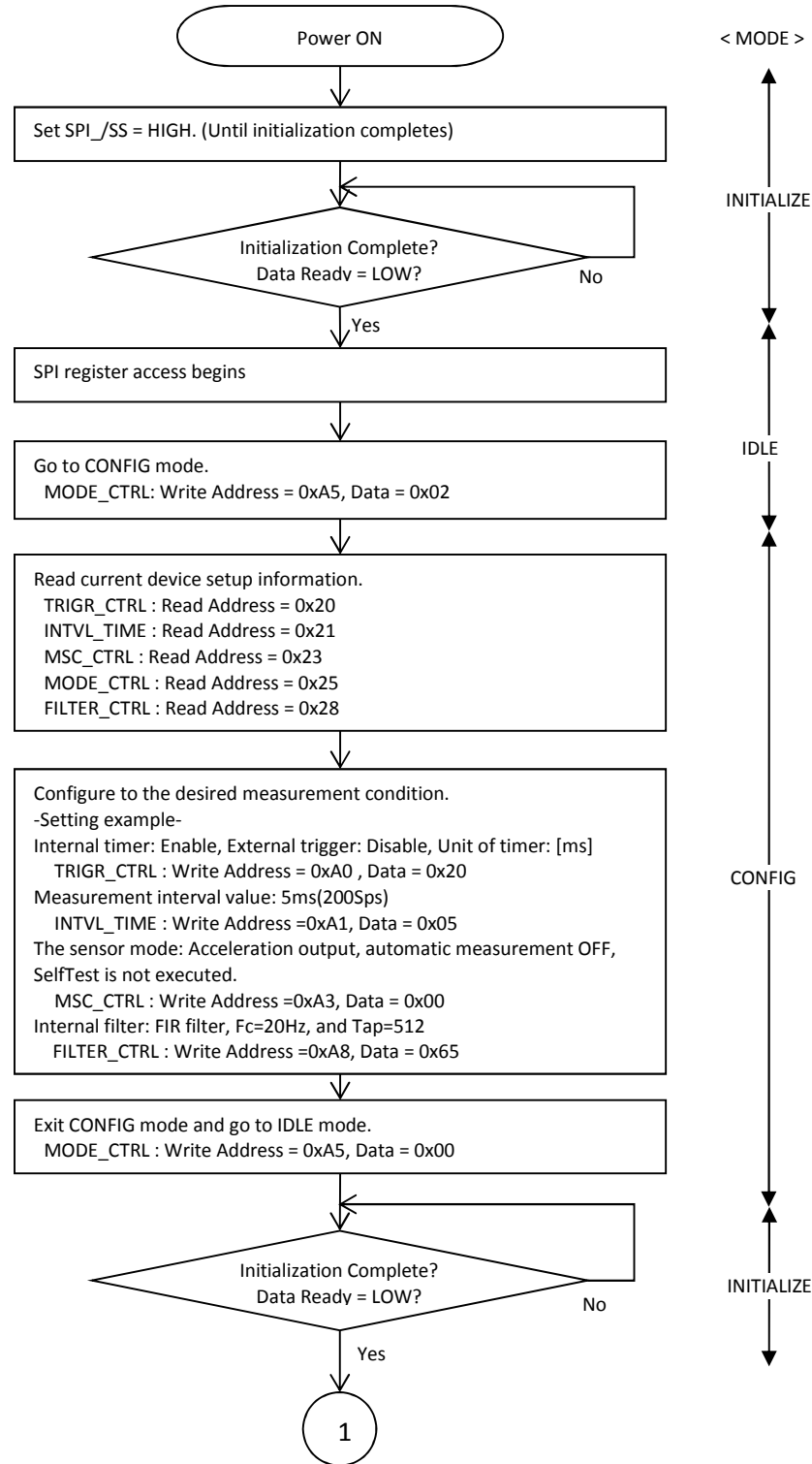
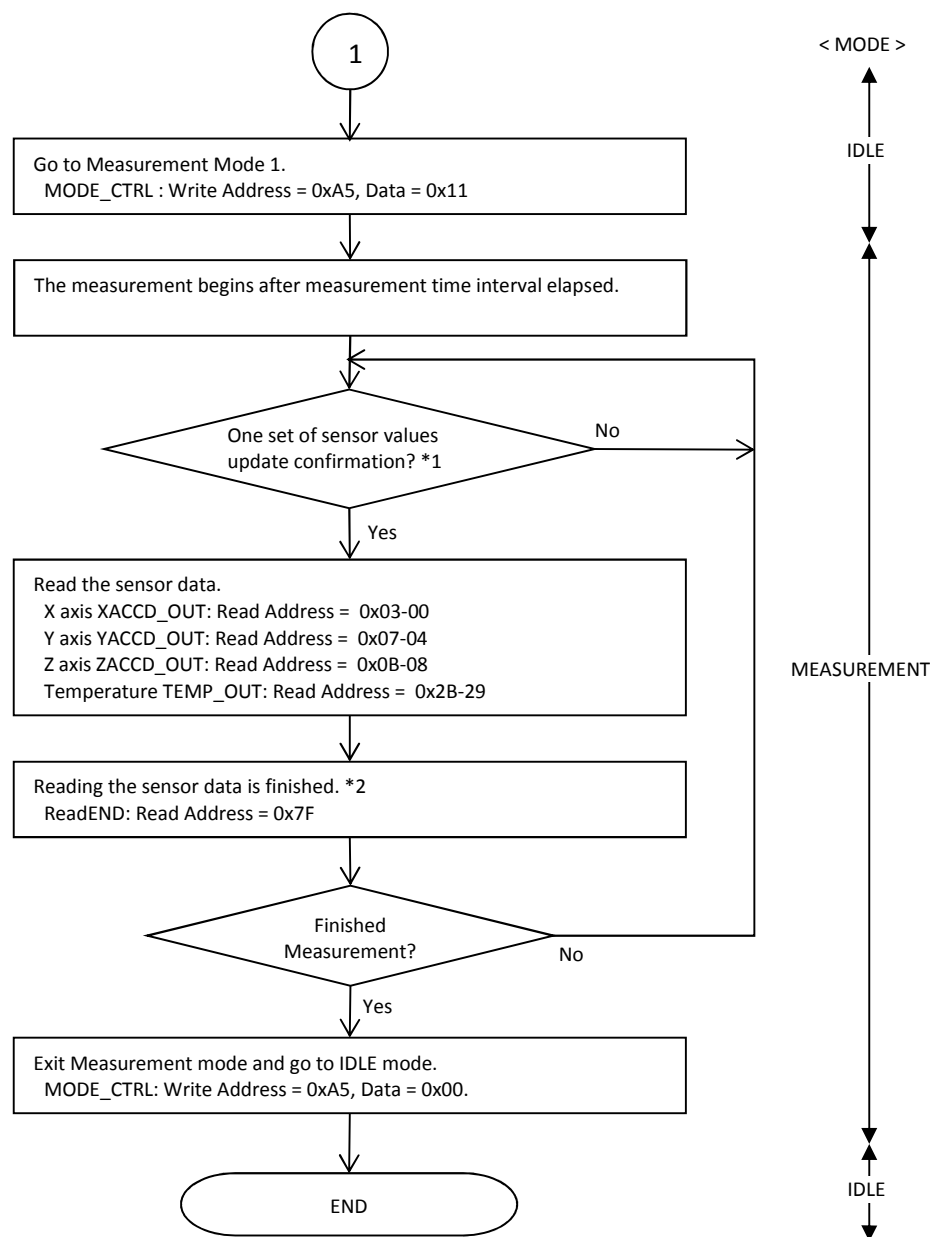


Figure 6.12 Example of Measurement Setup by Register - 1



SUPPLEMENTAL NOTE:

*1. When the sensor value is updated by a single shot, internal timer or external trigger measurement, the Data Ready signal is asserted, Data Ready=HIGH.

*2. If ReadEND is issued, the Data Ready signal is negated, Data Ready=LOW.

Figure 6.13 Example of Measurement Setup by Register - 2

6.3 EXTERNAL TRIGGER INTERFACE

The external trigger terminal pin can be used to allow the host to trigger a device request to send sensor data or return the device back to the original factory shipment state.

6.3.1 SENSOR DATA TRANSMISSION REQUEST

The measurement circuit starts on the falling edge when a LOW pulse (min.1 μ s) is detected on the external trigger terminal (EXT_TRG) when the device is in measurement mode and the measurement trigger source is set to external trigger. After receiving the trigger, the acceleration is measured, and the result is transmitted to the host. For more information, refer to Section 2.6 External Trigger Timing Specifications.

6.3.2 RESET TO THE FACTORY DEFAULT SETTINGS

The product can be reprogrammed to the original default factory setting by following the below procedure:

Procedure for returning the device to the default factory state

1. Set the terminal EXT_TRG = LOW when the power supply is turned on or when the device is re-initialized by command (ATENDCFG/MODE_CTRL) after a configuration change.
2. Hold the terminal EXT_TRG LOW for until the LED is blinking in Pattern 0 (about 6.6 seconds).
3. After LED blinks pattern 0, the default factory values have been successfully programmed from non-volatile memory. The terminal EXT_TRG can be safely set back to HIGH.

The following is the default factory setting for the device:

UART Setting:	UART=460800,N,1	(460800bps, Parity=None, Stop=1bit)
Output Format:	DFRM=0,1,XYZ	(acceleration, temperature, X+Y+Z axis)
Physical Output:	PYCL=1,1,0	(X axis: Angle, Y axis: Angle, Z axis: Acceleration)
		Only effective when output is compound measurement mode
Trigger Setting:	DTRG=2,00005,0	(external trigger=disabled, internal timer=enabled, output rate 5ms)
Internal Filter:	FILT=1,2,512	(FIR filter, Fc=20Hz, 512Tap)
Bias Correction:	BIAS=0,0,0	(X axis: 0uG and Y axis: 0uG and Z axis: 0uG)
Automatic Measurement:	AUTO=OFF	(automatic measurement function OFF)

NOTE: The default factory setting for SPI version is the same as the UART version. Refer to Table 6.10 Register Map for more information.

7. PACKING DIMENSIONS

The shipment packaging of this product is described below.

Tray Storage

The product is stored inside electrostatic bag within a tray.

Electrostatic Bag t0.5 x W105 x H150 mm

Tray W119 x D89 x H15 mm

Units per Tray 1 Units

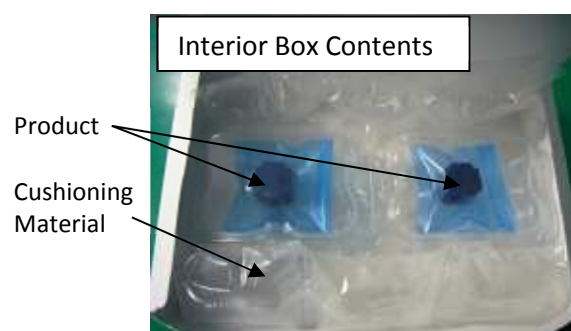
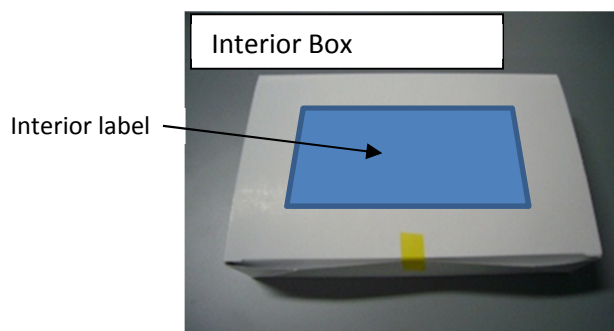


Interior Box Storage

The tray containing the product is stored in a interior box with cushioning material.

Interior Box W253 x D158 x H49 mm

Units per Box 2 Trays (Max)



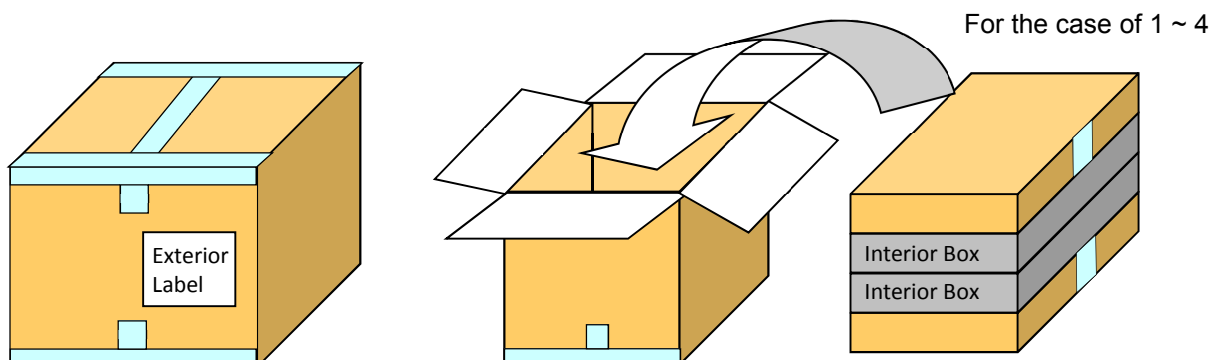
Exterior Box Storage

The interior box is stored in an exterior box with size proportional to the number of products.

Table 7.1 Exterior Box Dimensions (mm)

W	D	H	Products per Box
260	175	150	1 ~ 4
335	260	150	5 ~ 8

The interior boxes are placed in between Spacers and stored in the exterior box.



Labels

(1) Inner box label

Attach a label with the following content.

① Format

発注者 (CUST.)	A	SEIKO EPSON CORP.	K
受渡場所名 (DELIVERY POINT)	B	P/N1	
納品キ一番号 (TRANS. No.)	C	P/N2	
品名コード (PART No.)	D	P/N3	
品名(PART NAME)	E	M	P
入数/納入数量 (QTY/TOTAL QTY)	F-1	F-2	単位 PC (UNIT)
発注者用備考(CUSTOMER'S REMARKS)	G	包装個数(PACKAGE COUNT)	N
(3N)3  H (3N)4  I (3N)5  J SEIKO EPSON CORP. O MADE IN JAPAN			

② Content of label

Number	List of the content on the D label
A	Customer's name
B	Delivery point
C	Customer's P/O Number + Installment delivery Number
D	Displays P/N1.
E	Part name
F-1	Quantity
F-2	Total quantity
G	Customer's remarks
H	Barcode to display the Number C + Number of delivered items
I	Barcode to display the Number D + Quantity
J	Barcode information for the customer and the vendor
K	Shipping date
P/N1	See the list below
P/N2	See the list below
P/N3	See the list below
M	Epson management number (Epson arrangement number)
N	Package count
O	Country of origin
P	Specified chemical substances content display
	Display method when supporting RoHS: [[G]]RoHS
	Display method when containing Pb: [[Pb]]

③ Type of label

	For E/U model number, part name, product model number	For Part name, product model number	For Product model number
P/N1	E/U model number	Part name	Product model name
P/N2	Part name	Part name	-
P/N3	Product model name	Product model name	Product model name

(2) Shipping box label

Attach a label with the following content.

① Format

発注者 (CUST.)	A	SEIKO EPSON CORP.	K
受渡場所名 (DELIVERY POINT)	B	P/N1	
納品キ-番号 (TRANS. No.)	C	P/N2	
品名コード (PART No.)	D	P/N3	
品名(PART NAME)	E	M	P
入数/納入数量 (QTY/TOTAL QTY)	F-1	F-2	単位 PC (UNIT)
発注者用備考(CUSTOMER'S REMARKS)	G	包装個数(PACKAGE COUNT)	N
(3N)3 H  (3N)4 I  (3N)5 J  SEIKO EPSON CORP. O MADE IN JAPAN			

② Content of label

Number	List of the content on the D label
A	Customer's name
B	Delivery point
C	Customer's P/O Number + Installment delivery Number
D	Displays P/N1.
E	Part name
F-1	Quantity
F-2	Total quantity
G	Customer's remarks
H	Barcode to display the Number C + Number of delivered items
I	Barcode to display the Number D + Quantity
J	Barcode information for the customer and the vendor
K	Shipping date
P/N1	See the list below
P/N2	See the list below

P/N3	See the list below
M	Epson management number (Epson arrangement number)
N	Package count
O	Country of origin
P	Specified chemical substances content display
	Display method when supporting RoHS: [[G]]RoHS
	Display method when containing Pb: [[Pb]]

③ Type of label

	For E/U model number, part name, product model number	For Part name, product model number	For Product model number
P/N1	E/U model number	Part name	Product model name
P/N2	Part name	Part name	-
P/N3	Product model name	Product model name	Product model name

Packed quantity

Maximum capacity 8 units/box

Items included

Test report 1/unit (for each product)

Storage environment

- Avoid direct sunlight and store at room temperature and low humidity.
- Avoid applying external pressure onto stored inner/shipping boxes.

8. TEST REPORT

The following is an example the test report for this product.



TEST REPORT

PRODUCT NAME: M-A351A*	MODEL: *****
SERIAL No: *****	STATUS : *****

Parameter	Test Conditions/ Comments	Data			Criteria			Unit	Result
		X axis	Y axis	Z axis	Min.	Typ.	Max.		
Bias	@23°C±5°C				-4		4	mG	
Misalignment	@23°C±5°C, ±1G				-0.1		0.1	deg.	
Nonlinearity	@23°C±5°C, ±1G				-0.03		0.03	%	
Bias Temp. Change	-20 ~ +85°C				-4		4	mG	
Noise density	@23°C±5°C 0.5 ~ 6Hz Ave.						2.0	μGrms /√Hz	
Power Supply Current	@23°C±5°C, 3.3V						27	mA	

DATE : ****/**/****

INSPECTED BY : *****

CHECKED BY : *****

9. SAMPLE PROGRAM FLOW

The recommended procedure for operate this product is shown below.

9.1 UART FLOW

9.1.1 Power-on sequence

- 1) Power-on.
- 2) Wait Power-On Start-Up Time. /* Initialization */
- 3) Result: "Init.M-A351\r\n" /* Initialization End */

9.1.2 Read sensor configuration setting

- 1) Change to config mode from idle mode.
Command: "ATCONFIG\r\n"
Result: "\r\nOK\r\n"
- 2) Read sensor configuration setting.
Command: "ATRDDTRG\r\n"
Result: "DTRG=2,00005,0\r\n" /* Ext.Trigger=Disable, Timer=Enable, Interval=5ms(200Sps) */
Result: "\r\nOK\r\n"
Command: "ATRDDFRM\r\n"
Result: "DFRM=0,1,XYZ\r\n" /* Fomat=XYZ-axis Acceleration output with Temperature */
Result: "\r\nOK\r\n"
Command: "ATRDFILT\r\n"
Result: "FILT=1,2,512\r\n" /* Filter type=FIR filter, Fc=20Hz, Tap=512 */
Result: "\r\nOK\r\n"
Command: "ATRDAUTO\r\n"
Result: "AUTO=OFF\r\n" /* Auto measure mode OFF */
Result: "\r\nOK\r\n"
Command: "ATRDBIAS\r\n"
Result: "BIAS=0,0,0\r\n" /* Bias calibration=X:0uG, Y:0uG, Z:0uG */
Result: "\r\nOK\r\n"
Command: "ATTSTSLF\r\n"
Result: "O1\r\n" /* Vdd SelfTest=OK */
Result: "O2\r\n" /* NVRAM SelfTest=OK */
Result: "O3\r\n" /* Clock SelfTest=OK */
Result: "O4\r\n" /* Acc.Sensor SelfTest=OK */
Result: "O5\r\n" /* Temp.Sensor SelfTest=OK */
Result: "O6\r\n" /* IRAM SelfTest=OK */
- 3) Change to idle mode from config mode.
Command: "ATENDCFG\r\n"
Result: "\r\nOK\r\n"

9.1.3 Write sensor configuration setting

- 1) Change to config mode from idle mode.
Command: "ATCONFIG\r\n"
Result: "\r\nOK\r\n"
- 2) Write sensor configuration setting.
[External trigger only]
Command: "ATWRDTRG=1,00005,0\r\n" /* Ext.Trigger=Enable, Timer=Disable, Interval = 5ms(200Sps)*/
Result: "\r\nOK\r\n"
[Internal timer only]
Command: "ATWRDTRG=2,00005,0\r\n" /* Ext.Trigger=Disable, Timer=Enable, Interval =5ms(200Sps) */
Result: "\r\nOK\r\n"
Command: "ATWRDDFRM=0,1,XYZ\r\n" /* Fomat=XYZ-axis Acceleration output with Temperature */
Result: "\r\nOK\r\n"

```

Command: "ATWRFILT=1,2,512\r\n"      /* Filter type=FIR filter, Fc=20Hz, Tap=512 */
Result: "\r\nOK\r\n"
Command: "ATWRAUTO=OFF\r\n"          /* Auto measure mode OFF */
Result: "\r\nOK\r\n"
Command: "ATWRBIAS=0,0,0\r\n"        /* Bias calibration=X:0uG, Y:0uG, Z:0uG */
Result: "\r\nOK\r\n"
3) Change to idle mode from config mode.
   Command: "ATENDCFG\r\n"
   Result: "\r\nOK\r\n"
                                     /* Write to NVRAM after receiving ENDCFG command.
4) Wait Initialization Time.          /* Initialization */
5) Result: "Init.M-A351\r\n"          /* Initialization End */

```

9.1.4 Measurement Mode1

```

1) Change to Measurement mode1 from idle mode.
   Command: "ATMESMD1\r\n"
   Result: "\r\nOK\r\n"
2) Wait Measurement Wait Time.
3) Measurement start.
   [External trigger]
   a) External trigger input.
   b) Result: HD,DL,X3,X2,X1,X0,Y3,Y2,Y1,Y0,Z3,Z2,Z1,Z0,T2,T1,T0,CS,CR,LF /* Binary data output */
                                     /* Sample Data */
                                     /* "80 14 00 05 26 97 00 04 19 CC 00 FF 99 C6 00 78 B1 46 0D 0A" */
                                     /* HD=0x80(Accelerometer) */
                                     /* DL=0x14(Data Length=20Byte) */
                                     /* X=0x00052697/2^24=0.020120...[G] */
                                     /* Y=0x000419CC/2^24=0.016018...[G] */
                                     /* Z=0x00FF99C6/2^24=0.998440...[G] */
                                     /* T=0x0078B1/2^10=30.172...[deg] */
                                     /* CS=0x46(CeackSum=0x14+0x0+0x5+0x26+0x97+0x0+0x4+0x19+0xCC+0x0+0xFF+0x99+0xC6+0x0+
                                     0x78+0xB1=0x546 least significant byte) */
   Repeat from a) to b).
   [Internal Timer]
   /* Sensor data are output repeatedly by Internal timer. */
   b) Result: HD,DL,X3,X2,X1,X0,Y3,Y2,Y1,Y0,Z3,Z2,Z1,Z0,T2,T1,T0,CS,CR,LF /* Binary data output */
   [Request Command]
   a) Command: "ATREQDAT\r\n".
   b) Result: HD,DL,X3,X2,X1,X0,Y3,Y2,Y1,Y0,Z3,Z2,Z1,Z0,T2,T1,T0,CS,CR,LF /* Binary data output */
   Repeat from a) to b).
4) Measurement end and change to idle mode from Measurement mode1.
   Command: "ATENDMES\r\n"
   Result: "\r\nOK\r\n"

```

9.2 SPI FLOW

9.2.1 Power-on sequence

```

1) Power-on.
2) SPI_/SS signal set high level during initialization after power-on.
2) Wait Power-On Start-Up Time.      /* Initialization */
3) Check that Data ready is Low level. /* Initialization End */

```

9.2.2 Read sensor configuration setting

```

1) Change to config mode from idle mode.
   MOSI: 0xA5, 0x02      /* MODE_CTRL */
   MISO: 0x--, 0x--      /* There is no response at Write. */
2) Read sensor configuration setting.

```

```

MOSI: 0x25, 0x-- /* MODE_CTRL */
MISO: 0x--, 0x08 /* The current operating mode is Configuration mode. */
MOSI: 0x20, 0x-- /* TRIGR_CTRL */
MISO: 0x--, 0x20 /* Ext.Trigger=Disable, Timer= Enable, Time.Unit=ms */
MOSI: 0x21, 0x-- /* INTVL_TIME */
MISO: 0x--, 0x05 /* Interval =5ms */
MOSI: 0x23, 0x-- /* MSC_CTRL */
MISO: 0x--, 0x00 /* Auto measure=off, Model type=Acceleration */
MOSI: 0x28, 0x-- /* FILTER_CTRL */
MISO: 0x--, 0x65 /* Filter type=FIR filter, Fc=20Hz, Tap=512 */
MOSI: 0x53, 0x52, 0x-- /* X-BIAS_CTRL */
MISO: 0x--, 0x00, 0x00 /* Bias calibration=X:0uG */
3) Change to idle mode from config mode.
MOSI: 0xA5, 0x00 /* MODE_CTRL */
MISO: 0x--, 0x-- /* There is no response at Write. */

```

9.2.3 Write sensor configuration setting

```

1) Change to config mode from idle mode.
MOSI: 0xA5, 0x02 /* MODE_CTRL */
MISO: 0x--, 0x-- /* There is no response at Write. */
2) Write sensor configuration setting .
[External trigger only]
MOSI: 0xA0, 0x10 /* TRIGR_CTRL:Ext.Trigger=Enable, Timer=Disable, Time.Unit=ms */
MISO: 0x--, 0x-- /* There is no response at Write. */
[Internal timer only]
MOSI: 0xA0, 0x20 /* TRIGR_CTRL:Ext.Trigger=Disable, Timer=Enable, Time.Unit=ms */
MISO: 0x--, 0x-- /* There is no response at Write. */
MOSI: 0xA1, 0x05 /* INTVL_TIME: Interval =5ms */
MISO: 0x--, 0x-- /* There is no response at Write. */
MOSI: 0xA3, 0x00 /* MSC_CTRL */
MISO: 0x--, 0x-- /* Auto measure=off, Model type= Acceleration */
MOSI: 0xA8, 0x65 /* FILTER_CTRL */
MISO: 0x--, 0x-- /* Filter type=FIR filter, Fc=20Hz, Tap=512 */
MOSI: 0xD3, 0x00, 0xD2, 0x00 /* X-BIAS_CTRL */
MISO: 0x--, 0x--, 0x--, 0x-- /* Bias calibration=X:0uG */
3) Change to idle mode from config mode.
MOSI: 0xA5, 0x00 /* MODE_CTRL */
MISO: 0x--, 0x-- /* There is no response at Write. */
/* After receiving "0xA5, 0x00", Data Ready is changed to high level
and the settings are written to NVRAM */
4) Wait Initialization Time. /* Initialization */
5) Check that Data ready is low level. /* Initialization End */

```

9.2.4 Measurement Mode1

```

1) Change to measurement mode1 from idle mode.
MOSI: 0xA5, 0x11 /* MODE_CTRL */
MISO: 0x--, 0x-- /* There is no response at Write. */
2) Wait Measurement Wait Time.
3) Measurement start.
[External trigger]
a) External trigger input.
b) Wait until Data ready signal is asserted.
c) Read the sensor values.
MOSI: 0x00, 0x01, 0x02, 0x03, 0x04, 0x05, 0x06, 0x07, 0x08, 0x09, 0x0A, 0x0B, 0x29, 0x2A, 0x2B, 0x7F
MISO: 0x--, X0, X1, X2, X3, Y0, Y1, Y2, Y3, Z0, Z1, Z2, Z3, T0, T1, T2
/* X*,Y*,Z* : Sensor output data, T* : Temperature output data */
/* Sample Data */
/* X3=00,X2=05,X1=26,X0= 97,Y3=00,Y2=04,Y1=19,Y0=CC,Z3=00,Z2=FF,Z1=99,Z0=C6,T2=00,
T1=78,T0=B1*/
/* X=0x00052697/2^24=0.020120...[G] */

```

```

/* Y=0x000419CC/2^24=0.016018...[G] */
/* Z=0x00FF99C6/2^24=0.998440...[G] */
/* T=0x0078B1/2^10=30.172...[deg] */

```

Repeat from a) to c).

[Internal Timer]

a) Wait until Data ready signal is asserted by the internal timer.

b) Read the sensor values.

MOSI: 0x00, 0x01, 0x02, 0x03, 0x04, 0x05, 0x06, 0x07, 0x08, 0x09, 0x0A, 0x0B, 0x29, 0x2A, 0x2B, 0x7F

MISO: 0x--, X0, X1, X2, X3, Y0, Y1, Y2, Y3, Z0, Z1, Z2, Z3, T0, T1, T2

/* X*,Y*,Z* : Sensor output data, T* : Temperature output data */

Repeat from a) to b).

[Single measurement]

a) Do a single measurement.

MOSI: 0xA5, 0x13 /* MODE_CTRL */

MISO: 0x--, 0x-- /* There is no response at Write. */

b) Wait until Data ready signal is asserted.

c) Read the sensor values.

MOSI: 0x00, 0x01, 0x02, 0x03, 0x04, 0x05, 0x06, 0x07, 0x08, 0x09, 0x0A, 0x0B, 0x29, 0x2A, 0x2B, 0x7F

MISO: 0x--, X0, X1, X2, X3, Y0, Y1, Y2, Y3, Z0, Z1, Z2, Z3, T0, T1, T2

/* X*,Y*,Z* : Sensor output data, T* : Temperature output data */

Repeat from a) to c).

4) Measurement end and change to idle mode from measurement mode1.

MOSI: 0xA5, 0x00 /* MODE_CTRL */

MISO: 0x--, 0x-- /* There is no response at Write. */

9.2.6 Software reset

1) Send software reset command.

MOSI: 0xE0, 0x01 /* RESET_CTRL */

MISO: 0x--, 0x-- /* There is no response at Write. */

/* After receiving "0xE0, 0x01", Data Ready is changed to high level. */

4) Wait Initialization Time.

/* Initialization */

5) Check that Data ready is low level.

/* Initialization End */

Notes for SPI

1) Wait tSTALL as register access interval.

2) Wait tWEXE for write processing after sending Write command.

3) SPI data "0x--" : don't care.

10. HANDLING NOTES

10.1 CAUTIONS FOR USE

- When you attach the product to a housing, equipment, jig, or tool, make sure you attach it properly so that no mechanical stress is added to create a distortion such as a warp or twist. In addition, tighten the screws firmly but not too firmly because the mount of the product may break. Use screw locking techniques as necessary.
- When you set up the product, make sure the equipment, jigs, tools, and workers maintain a good ground in order not to generate high voltage leakage. If you add overcurrent or static electricity to the product, the product may be damaged permanently.
- When you install the product, make sure metallic or other conductors do not enter the product. Otherwise, malfunction or damage of the product may result.
- If excessive shock is added to the product when, for example, the product falls, the quality of the product may be degraded. Make sure the product does not fall when you handle it.
- Before you start using the product, test it in the actual equipment under the actual operating environment.
- Since the product has capacitors inside, inrush current will occur during power-on. Evaluate in the actual environment in order to check the effect of the supply voltage drop by inrush current in the system.
- If water enters the product, malfunction or damage of the product may result. If the product can be exposed to water, the system must have a waterproof structure. We do not guarantee the operation of the product when the product is exposed to condensation, dust, oil, corrosive gas (salt, acid, alkaline, or the like) , or direct sunlight.
- This product is not designed to be radiation resistant.
- Never use this product if the operating condition is over the absolute maximum rating. If you do, the characteristics of the product may never recover.
- If the product is exposed to excessive exogenous noise or the like, degradation of the precision, malfunction, or damage of the product may result. The system needs to be designed so that the noise itself is suppressed or the system is immune to the noise.
- Mechanical vibration or shock, continuous mechanical stress, rapid temperature change, or the like may cause cracks or disconnections at the various connecting parts.
- Take sufficient safety measure for the equipment this product is built into.
- This product is not intended for general use by the consumer but instead for engineering design. For the customer, please consider it safely with the proper use.
- This product is not designed to be used in the equipment that demands extremely high reliability and where its failure may threaten human life or property (for example, aerospace equipment, submarine repeater, nuclear power control equipment, life support equipment, medical equipment, transportation control equipment, etc.). Therefore, Seiko Epson Corporation will not be liable for any damages caused by the use of the product for those applications.
- Do not alter or disassemble the product.

10.2 CAUTIONS FOR STORAGE

- Do not add shock or vibration to the packing box. Do not spill water over the packing box. Do not store or use the product in the environment where dew condensation occurs due to rapid temperature change.
- To suppress the characteristic change by prolonged storage, it is recommended to maintain the environment at normal temperature and normal humidity. Normal temperature: +5 ~ +35 °C Normal humidity: 45%RH ~ 85%DH (JIS Z 8703).
- Do not store the product in a location subject to High Temperature, high humidity, under direct sunlight, corrosive gas or dust.
- Do not put mechanical stress on the product while it is stored.

10.3 OTHER CAUTIONS

- Evaluate the product requirements in a real system or real machine before using.

-
- The product contains quartz crystal oscillator created by microfabrication. Take precaution to prevent falling or excessive impact. Do not use the product after an accidental fall or it experiences excessive impact. The possibility of a failure and risk of malfunction from failure increases.
 - The environmental vibration frequency may affect the resonance frequency of this product. So, please evaluate the product thoroughly to meet user and system requirements before using.
 - If a radio (transmission antenna) is set up near this product, degradation of the precision may result by radio frequency interference. Place the radio (transmission antenna) as far away as possible or add shielding to mitigate the effects of radio frequency interference.
 - Never turn off power while the host communicates the product. Otherwise, malfunction of the product may result.
 - For best performance, allow the product 15 minutes or more warm-up period after the power supply is turned on before taking measurements.
 - Small performance deterioration due to long-term use and aging effects, etc. cannot be detected through the self-diagnosis test in this product. Discontinue use immediately even when the self-diagnosis test results in a "pass" when experiencing abnormality in the sensor performance.
 - If noise is induced on the external trigger terminal, there is a possibility an invalid measurement process is unintentionally sent to the host. To prevent this, disable the external trigger setting if you do not use an external trigger, or when using an external trigger, take precaution to minimize noise on the external trigger terminal.
 - Exercise care and precaution with the packaging and during transport of the equipment that this product is installed on to avoid excessive vibration and or damage from impact.

10.4 LIMITED WARRANTY

- The product warranty period is one year from the date of shipment.
- If a defect due to a quality failure of the product is found during the warranty period, we will promptly provide a replacement.

11. PART NUMBER / ORDERING INFO.

The product can be ordered with the following numbers. Please inquire separately about details.

Table 11.1 Product Model Number and Host Interface

Product Model Number	Product Name	Host Interface
E91E606220	M-A351AS10	SPI
E91E606230	M-A351AU10	UART

12. EVALUATION TOOLS

Evaluation tools can be provided for the M-A351AU. For details, contact our representatives.

Table 12.1 Evaluation Tool Model Number

Product Model Number	Product Name	Comments
E92E606141	M-C30EV141	USB Serial Converter Cable for EPSON M-A351AU. Works with Logger Software.

REVISION HISTORY

Applying -1

Rev. No.	Date	Page	Type	Content of revision (An old content is included).
Rev1.0	2016/2/10	Full page	New	new enactment
Rev20171027	2017/10/27	Cover	Update	Notice
		4	Added	Resonant Frequency
		11	Update	Figure 4.1 Noise Density Characteristic
		58, 59	Update	Handling notes

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